SUNFLOWER

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FOR FOOD, FODDER AND FERTILITY

Its economic value, world expansion and cultivation with particular application to Great Britain

by

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FOREWORD

'The sunflowers along the fence, for the chickens, had heads as big as plates.' —Extract from a picture of American life in *The Yearling*, MARJORIE KINNAN RAWLINGS.

As the subject of this book concerns, directly or indirectly, every individual in these islands, I have endeavoured to cover all aspects, since only by comprehension of these will the citizen understand the importance of Sunflower to himself and his family; the farmer and the smallholder appreciate the part they can play, to their own advantage and the advantage of the land they hold in trust for the nation.

Basically my subject is 'Food'. More precisely it is protective food, in the form of vitamin oils and vegetable fats, so essential for health and well-being. Sunflower, which is the most extensively grown oilseed crop and the most adaptable to all climates, is a prime provider of these fats and oils. But sunflower also can be a great factor in the fertility of our land.

In the main text I have endeavoured to avoid over-much technical detail but much can be referred to by the specialist under the appropriate chapters and, for those wishing to enter into greater detail on any special angle, a list of some works of reference will be found in the appendices.

I do not pretend to have attained completeness. In fact, since the accretion of knowledge is progressive, as has been said by others, no text-book of any merit can ever claim completeness and a supplement is inevitable at some later date. But so important has the future feeding of our country become and so important the future fertility of our land, that it would have been unwise to delay longer before putting down what has already been learned by experience for the guidance of others.

Unfortunately too much that is untrue or misleading has appeared in print, either from journalists with no knowledge of the facts or by other persons, some of whose sole claim to acquaintance with the crop dates back to Czarist Russia and the very primitive methods of harvesting crops, that had been broadcast sown, under entirely different conditions to those obtaining here. Not only does what has been said by the latter show that they have little or no knowledge of either the biology or histology of the sunflower, but they can claim no experience in artificial drying and its technique for this particular crop, which not only differs

from that applicable to grain crops but is not, of course, even practised abroad. I have therefore considered it worth while to deal with the whole subject at some length and in considerable detail so that what knowledge has been gained in the past years may be made available to all potential growers and the future prospects of this important crop be assisted as far as possible.

The predicament which faced this country in 1940–1, before the introduction of Lend-Lease, due to shipping shortage and increasing losses, showed most plainly in the restricted supplies of milk, meat, eggs and fats. How serious this was may not have been realized by 'the man in the street', though it was continually reflected in our rationing. But one fact that was realized, by a very small minority only, was how easily, had it not been for the traditional *laissez faire* policy of food imports and British agriculture, it could have been avoided.

It was at this juncture that, with some previous experience of the value of sunflower as an oil seed crop, both here and in Russia, I put forward the suggestion of its adoption in this country in various sections of the Press, arousing thereby the encouragement of many. I had the good fortune to come in touch with Mr. G. E. Blackman,[1] of the Imperial College of Science and Technology, London, who was technically interested in experimental oil seed crops. When the Ministry of Agriculture decided in 1941 to make a grant to the Imperial College, London, Mr. Blackman was enabled to widen his scope, working, on loan, under the latter body. His work has been largely biological and experimental. But, by a happy combination of co-operation, it has been possible to widen the acreage of this crop on a farm scale during the past three years so that, to-day, we can fairly say that it is a healthy infant, prepared from now on to grow rapidly and fulfil its destiny of helping to save the food supplies of the country in the much more difficult post-war years.

If it is officially agreed that vegetable oils are the outstanding world shortage,[2] that this problem will become more acute as peace-time conditions return, and that we, in this country, must be in a position to meet our own needs by home production, chiefly from sunflower, then some steps must be taken, also officially, to put this production on a sound and progressive basis in the shortest possible time.

It may be useful to review briefly what has actually transpired in the past three or four years.

Apart from extensive trials in regard to selection of varieties, the technique of cultivation and harvesting, etc., officially carried out under

[1] Appointed Sibthorpian Professor of Rural Economy at Oxford (1945).

[2] Statement made by successive Ministers of Agriculture and others.

grant, growing on a farm scale commenced in 1942. The farm acreage, under official supervision, was increased, both in acreage and the territory covered, in 1943. For the latter purpose supplies of suitable seed were imported from abroad and distributed by the Ministry, either to the seed trade, direct to growers, or through myself, to certain selected growers, so as to cover as wide a variation in soils and conditions as possible. These two latter categories comprised those crops which were supervised by the Research Council for the accumulation of data.

A considerable amount of seed resulted from the harvests. At first, the Ministry chiefly envisaged this crop as an ultimate means of providing the poultry keeper with stock seed to grow his own grain, and so relieve the feeding stuffs situation under war conditions. But it was also intended that the seed should be used to increase gradually the available stocks and so, each year, widen the acreage which would be grown throughout the country. Naturally enough, knowing little about the technique of artificial drying of sunflower seed or the suitability of existing machinery for threshing or drying, a considerable quantity of seed was damaged to an extent which made it unsuitable for reproduction. On the other hand, due to failure of control from above, additional quantities of sound seed of good germination undoubtedly found its way into the hungry beaks of cage birds. Under the circumstances this was hardly surprising, especially as the bird seed trade and bird fanciers were willing to pay very high prices for such seed, under existing scarcity conditions.

After the 1943 season I suggested to the Seed Board that a fair price should be generally agreed to growers, with a reasonable profit to the driers and those who handled agricultural seeds and who were responsible for erecting costly experimental plant, roguing crops, selecting, grading and distributing seed and supervising harvesting operations; that either the Ministry should fix a price for seed for future resowing and make some control whereby high quality pure seed was not diverted to other channels, or that they should themselves purchase the whole crop and make a redistribution through channels suitable for the different grades.

Unfortunately some difference of opinion took place in official circles and nothing was done about this in 1944 but it does seem as if this industry, in view of its admitted importance for the post-war years, should, at the start, have been properly organized and given a lead from above. At the moment it is the plaything of various interests—the agricultural seed trade, the bird seed trade, some earnest growers, and a number of speculators. This not only leads to absurd prices being offered

and paid but to a range of prices that must alarm the grower in their instability; for he sees that the price must drop ultimately to a level, which not only can no one predict years ahead but which cannot even be fixed for the succeeding season. Even the N.F.U. have taken a hand. Some talk was made about the formation of a Sunflower Committee for that body and later they announced that they were negotiating prices with the seed trade. Nothing seemed to come of the latter negotiations and the market was allowed to find its own level—which has been very far from 'level'.[1] As regards any advisory committee, it seems that the Farm Crop Dryers' Association Ltd., which has latterly become incorporated with the National Farmers' Union, and which organized a Sunflower Conference in London early in 1944 and later, early in 1945, incorporated Oilseed Drying as a separate item on the Agenda at a further Conference, might usefully extend their work in this direction. Alternately in view of the growing importance of oilseed crops in this country the N.F.U. might form a separate body to combine all forms of oilseed interests.[2] I am pleased to say that I have been able to help the work of the Farm Crop Driers' Association in their efforts.

But it must be realized that sunflower harvesting and drying problems are not parallel with those of other crops likely to be grown here for oil, for botanical and other reasons which will be spoken of. Also the local and climatic conditions of different parts of the country complicate the problem far more in the case of sunflower than with other crops.

It appears that sunflower should be treated in much the same way as were the flax and sugar beet industries and set on a correct and firm basis without delay, as a specialized branch of agriculture. The price for selected strain seed for resowing can safely be left in the hands of the seed trade, by which means advances in breeding and selection will be encouraged and the price find its own market level. But prices of seed for all other purposes should be fixed officially at both ends, such seed

[1] Since writing the above an agreed price for high germination, pure variety seed, for resowing purposes, has been fixed as between the Seed Board, the N.F.U. and the Agricultural Seed Trade Association. But crushing seed is in a perilous position, due to the control of oils and fats by the Ministry of Food and internal pressure of vested interests. There appears to be a tendency, as in the case of linseed, to pay the home grower less than the overseas producer, in spite of the world shortage.

[2] Since writing the above a sub-committee of the National Farmers' Union has been formed to deal with considerations affecting certain specialized crops. These include oilseeds and a preliminary conference to discuss their possibilities was called in June 1946, when a rather general survey was made. Useful data was presented but with no concrete proposals for action.

should be graded and its uses clearly defined. This would entail the fixing of prices for seed for oil crushing on an oil-water content, the only fair way to all parties and following much the lines whereby sugar beet is paid for on sugar content and flax on length of fibre. This question needs immediate consideration.

Thus we shall have respectively fair prices for (1) selected strain seed, (2) seed suitable for reproduction, and (3) a range of grades for commercial uses. To merely leave the matter is to continue the chaos of the early years and to prolong the teething troubles. The public, including the farm grower, cannot at this stage be expected to distinguish between seed of indifferent strain and carefully selected, bred and tested seeds. Nor is it right to expect this latter to be marketed by the accredited seed trade at 2s. 6d. to 4s. per pound, when other agricultural seeds, existing in greater quantities and needing less expenditure to select, treat or breed, fetch five to ten times these prices.

Areas should be established with suitable harvesting and drying plant (see Appendix II), either through growers' associations, or as separate private enterprises, where the 'treating' plants are concerned.

As far as the Ministry[1] is concerned, the results of official research on sunflower crops should be published frequently and without delay, even if this entails interim reports on various angles connected therewith. It is better to give some good advice, for the health and upbringing of the growing baby, in good time than to issue a magnificent brochure, which in any case can never be final, when it has already fallen into a decline. Up to date the only such report, apart from an advisory leaflet, addressed mainly to backyard poultry keepers, issued in the summer of 1943, has been an article in the Ministry's journal, *Agriculture*. February 1944, summarizing some of the conclusions arrived at in the previous year, but publishing no concise accounts, particularly such useful things as graphs of spacing trials and oil or vitamin figures and analyses. Any such data obtained by the Agricultural Research Council should, too, have a wider publication than the rather restricted circulation of the official journal, especially as the agricultural Press has been rather loath to write up,

[1] For the benefit of those, particularly abroad, who are not aware of the set-up for official research and development in agriculture in Britain, the position is as follows: Both the Ministry of Agriculture and the Agricultural Research Council, which itself received grants direct from the Treasury, give grants-in-aid of research to other bodies. The Agricultural Improvement Council, formed in 1943, bridges the gap between research and the farmer. It was the latter body which in 1944-45 gave encouragement and instructions to county War Agricultural Executive Committees to help the Imperial College research in development work in combine harvesting.

except from the 'news' angle, or encourage this crop 'off its own bat', evidently regarding it as, like the Loch Ness Monster, too novel to exist in fact.

Undoubtedly those interested in this crop and its products, notably the growers or areas, should, if its future is to be assured, at the earliest possible date consider combining and establishing an Association with an Advisory Council which would act as an intermediary between the interests represented, the seed trade and the Ministries of Agriculture and Food. In such an Association there would be room for the independent oil crushers and those handling feedingstuffs and other by-products. Such a body could undoubtedly promote further research on commercial lines and, if members would come forward openly with their problems and information, supply unbiased technical advice from a common pool. But the most important function of an Association would be to ensure that the grower was not thrown into the hands of a single buyer, when the crop is marketed for oil crushing, which could only result in starvation prices and the strangling of an industry that may be very essential for the nation's food supplies by a monopoly interest. In fact the cloven hoof of vested interest will have to be closely looked for and even in official quarters, where the hoof-mark is not apparent to the naked eye, it is necessary to be on the *qui vive* for a bulge in the back part of official pants which may well indicate the forked tail when the hooves are encased in patent leather boots. Suspicion of impeding action could be taken up by an Association through Parliamentary channels, in a way most difficult to the lone individual.

It might even be that the Government would be well advised to consider whether it was not necessary to assist such an Association, in much the same way—by grants—as has been done in the case of the Seaweed Association.

Obviously we do not want Government control, but rather Government assistance, guidance and protection, free from any policy that might be subject to political changes, guided by an economic long-term view, in purely national interests. The future of farming is always uncertain but in every new crop, particularly one of the nature of sunflower, both the agriculturalist and the market gardener have an addition to their rotation and, in many cases, what many of them have been seeking, something fresh that they can grow where established crops have ceased to pay or disease and pest-infected land make them impossible.

That private enterprise is useful in all new projects has often been proved, as for example in the case of flax, but private enterprise should be bound up with Government help and encouragement on business

lines and should not be left to be its own midwife and police force, when it is bringing forward something of vital national import.

Already I am pleased to feel that, as a result of a suggestion I put forward to the Ministry of Agriculture in 1943, 'area' growing has made a foothold in this country and, with the approval of the Agricultural Development Board, I was enabled to assist the establishment of the first two of these areas, with their own central drying plants, the one at Chipperfield in Hertfordshire and the other in Leicester, in 1944.

There will be plenty who will say, 'Why worry about the distant future? There will probably be no food shortage and we shall be able to make good on imports as before!' Or others who will ask, 'Are you concerned about the possibility of another war, when, after the coming peace settlement, there will be no more war, once the German question is settled?'

I still believe in taking the long view and that the lessons of history and the fact that human nature is what it is make it preferable to 'Be Prepared'. I am in fact bearing in mind that when, during the Munich period, a question was raised in Parliament as to the preparations being made for home food production, in case war broke out, the then Minister of Agriculture replied, 'What fools we should look if the war never happened!' This too followed the Austrian Anschluss, which had been presaged six months earlier by the free flow of German marks into Austria, a patent warning observable by every traveller, though members of the Cabinet later confessed that the Anschluss came as a complete surprise!

Germany may not start the next war, but history shows that the frequency of wars increases with the so-called 'advance' of civilization and the rule of the survival of the fittest holds good both in plant, animal and human life. So, without wishing to be a pessimist, it seems that the chances of further and even more embracing wars cannot be dismissed, when food will again be as important as armaments. If we are prepared in advance, a little extra—and a little fresher—home-produced food will not do us any harm, especially if its production increases our soil fertility, so that it can be stepped up more rapidly and with greater safety in case of dire necessity.

E. F. HURT

Yardley Gobion,
Northants.
September 1944.

AFTERTHOUGHTS

FOREWORD TO THE SECOND EDITION

"Hunger is cured by Food, Ignorance by Study."—CHINESE PROVERB.

It would seem that, in so far as those who assume to plan our well-being, particularly in Britain, Sanity and Clear Thinking, like Kipling's cat, keep themselves to themselves and 'walk alone'.

Without looking too far back in recent history it is only necessary to recall that, in 1945, the great 'Wheat Drive' policy was changed to 'More Meat, More Milk, Less Wheat'. But within a few months, realizing that he was in the position of a man in a bath who had overlooked the necessity for a towel, the Minister of Food had to announce, through his Sancho Panza, the Minister of Agriculture, a complete reversal of this last pronouncement while the ink on the paper was as yet hardly dry. To the disappointment of a public led to expect more variety of food and more dairy products and to the consternation of the already bewildered farmer the severest cut in feeding-stuffs was announced, accompanied by a reduction in all livestock, ranging from our largest herds to the backyarder's humble hens. Thus overnight the future of home produced supplies of meat, milk, eggs, butter and cheese became a mere mirage as 'More Wheat' was again called for, though at the date in question it was far too late to be effective in the current year. 'Sapiens qui Prospicit' is a motto those in brief authority are too apt to ignore!

Following shortly on this staggering reversal of policy it was decided that even bread and flour were to be rationed as from 21st July 1946. Yet within a few days of this last shattering blow, the Minister of Food, Mr. Strachey, addressing a more than disgruntled bakery trade, on 12th July, told them that *the Fats position was even more difficult than Cereals!*

One should be inclined to congratulate Sir Ben Smith, not on a job well done, but on knowing just when to save his face and step out, realizing, doubtless, that he, in his ignorance, had been led up the garden by his advisers. The whole story of the past few years is one of ineptitude, ignorance and lack of foresight, if nothing worse. One after another we in Britain have been cursed with a succession of Ministers of Food

and Agriculture who were unable to check, from their own knowledge and observation, the information and advice given to them by others, equally misguided, or to grasp the world economic position which had been slowly but surely developing over the past decade. The situation, tragic as it is, lacks only the satire of a Cervantes!

The people cannot live by bread alone; they need something to accompany it, something to spread on it; they have been crying out for more milk, more meat, more eggs, more fats, but they are offered bread without butter, dried eggs and, shades of ye fishermen of Cornwall, more pilchards!

To crown this folly, in August, our Minister of Food announces that greater imports of dairy produce have been arranged with Denmark. And, mark you, these imports are being made at such a price, 'because Denmark, having to import most of her feeding stuffs the cost of production is increased'; that, in spite of our crying need for foreign currencies, millions are to be spent on subsidies for these imports 'to keep the cost-of-living index down'. Has it never occurred to those who made this bargain that it would be better to increase our own livestock to produce here these dairy products, whether by growing more feeding stuffs at home or even by spending that part of the American loan devoted to the import of inedible films on such? At least we should save in cash the transport of food from Denmark plus the costs of production and wages which our subsidy pays to the Danes.

But subsidies on imported food, with the avowed object of keeping down the cost-of-living index, are surely akin to a mock auction. Is the public really so gullible as to imagine that a government subsidy is produced from thin air or Pandora's box. Either it must come in some form from the British taxpayer, the consumer of the goods—in which case the cost-of-living index is a faked figure—or it is the result of busy Treasury printing presses and merely swells the growing tide of inflation.

The example of Canada and other countries, who make themselves self-supporting on home-grown oilseed crops, stands out a mile but is ignored, although the Ministry of Agriculture has gone out of its way to prove, at no mean cost to the country, that Britain can produce a greater yield per acre of sunflower seed, with a higher oil content, than any other country in the world.

(*Note:* On 9th July 1945 the Secretary to the Minister of Food wrote, 'Colonel Llewellin is satisfied that . . . all necessary information is available within the Ministry which would enable a sound decision to be taken both in regard to prices and growing policy (of sunflower).' Yet the Director of Imports of Oils and Fats, chief adviser to the Minister,

informed the writer that he was unaware of what the Ministry of Agriculture had been doing in regard to sunflower and had not seen the report in the Ministry's journal, *Agriculture*, issued a few months previously!)

Sunflower was not on the list of controlled crops and oilseeds in the Ministry of Food Order of 1940, but once it began to expand on a farm scale, under the auspices of the Agricultural Research Council and the Agricultural Improvement Council, from seeds primarily imported by the Ministry of Agriculture, it began to interest, from one point of view, those responsible for the policy of the Ministry of Food. As a result of this, in 1944, the Minister of Food was induced to sign the 1944 Order, No. 672, which prohibited any trade user from obtaining and any person from supplying any edible oil except under permit issued by the Minister. This order was a consolidation of the 1943 Order controlling the sales of edible oils and fats. Since permits to individuals were not forthcoming for crushing oilseeds except under direction of the Ministry of Food, who constituted themselves virtually the buyers of the seed, and since the Ministry quoted seventeen pounds per ton as the value of such seed grown in this country,[1] the grower had an uneconomical crop on his hands as far as oil production was concerned and found other markets—mainly the bird seed trade—so that even the public was deprived of these oils for cooking purposes as was the equally anxious pharmaceutical trade. The Ministry countenanced the selling of hundreds of tons of valuable seed—particularly valuable if it could have been resown to increase the acreage—for the feeding of parrots and the like because the Imports of Oils and Fats Division of the Ministry did not consider it advisable for oilseeds to be grown in Britain! This latter was probably the reason why, in 1945, the Ministry of Food were importing Linseed from India and the Argentine at £34, a price considerably over the £27 10s. per ton controlled price to the English grower, although the Ministry of Agriculture had published figures showing that our home-produced seed was of a far superior grade to that being imported! And the price of £17 per ton suggested for British grown sunflower seed, the truly valuable edible oil producer, was barely half that being paid for imported linseed!

It is probable that at the end of the 1945 harvest there was sufficient selected sunflower seed in the country to lay down 50,000 acres in 1946 and there would have been many times this amount had the 1943 and 1944 crops been saved for reproduction too. This acreage would have produced some 8,000 tons of high-grade, edible oil and a corresponding

[1] Quoted by the Deputy Director of Oils and Fats, 12th January 1945.

amount of cattle feeding cake, with a high protein content. When such a policy was suggested to the Ministry of Food one answer given was that home production would have entailed a consequent decrease in allotments from the combined Food Board though the Ministry was unable to explain why no decrease had been made in Canadian allotments, in view of the high production of oilseed crops, notably sunflower, in that Dominion. In fact, particularly when this extraordinary story is taken in conjunction with what has been happening in Canada and other countries it seems strange that an inquiry into the whole policy and working of the Ministry of Food's Oils and Fats Division has not been demanded by Parliament. •

U.S.A., Argentina, Uruguay, as well as many parts of the British Commonwealth, are stepping up sunflower seed production to meet their urgent needs. Canada has erected a special crushing plant in Toronto recently to deal with it and to extract the oil. In January 1946 the Dominion-Provincial Agricultural Conference urged Western farmers to grow 28,000 acres of sunflower this year, double their 1945 crop, as 'by so doing Canada would take a major step towards overcoming their lack of shortenings (cooking fats) and a fine edible meal for that purpose would be extracted, on the decision of the Dominion Department of Agriculture, with a 47 per cent protein content.'[1]

Britain lost this year 250,000 tons (equivalent to 130,000 tons of oil) of potential Indian groundnut,[2] while the embargo on Indian rape seed export further reduced our imports and we cannot make up these shortages from other sources. This state of affairs need have caused no surprise to anyone who had previously weighed up the facts and the above loss cannot be blamed in its entirety on poor harvests in India in a world where vegetable oils and fats were far below the needs of the world population even before the recent war. India and Egypt, both large suppliers of feeding cakes, are, in fact, due to financial world problems, using oilseed cakes for fertilizers and fuel to-day, the latter country because we cannot send her coal. History repeats itself!

Denmark, Holland, the U.S.A. and France are all competitors in the small world market for feeding stuffs and oilseeds to-day, as was inevitable once liberation was achieved. Yet, as has been pointed out, we are buying Danish dairy produce in increasing quantities in spite of

[1] Ottawa report, 29th January 1946.

[2] *Chemical Age*, London, 29th June 1946, and statement by Mr. Knight, Director of Oils and Fats Supplies, to the Ministry of Food, 13th February 1946.

the fact that she has to compete in this scramble for feeding cakes which she must import.

We have been living in a fool's paradise, directed by fools, where the one essential crop for the production of oil and feeding stuffs—as well as other valuable by-products—and consequently of milk, butter, meat and eggs, which we can so well grow, has been officially frowned upon and neglected, with malice aforethought. Again we are depending on the overseas producer, in spite of the shortage of foreign currency and export difficulties, and we are still in that same fool's paradise and in a worse hole than we were before the 'phoney peace' commenced with the cessation of hostilities! How far fixed currency exchanges, not based on a 'free market' value, assist exports is a matter for serious consideration but it is doubtful whether such artificiality in a world of free enterprise would be considered an asset to increased production, trade and prosperity.

The people have at least a right to ask why the Ministry of Food is 'groundnut mad' when most other countries are making themselves self-sufficient with sunflower, which we can not only grow better, but which yields essential proteins and the fertility vitamin, in addition to its very high grade oil. Lack of feeding stuffs and the consequent reduction in livestock is sapping the fertility of our land, the nation's heritage, capital and safeguard for the future. And to depend on overseas supplies may well place us in jeopardy again in case of another war!

E. F. HURT.

August 1946.

News Flash, October 1946. During the twelve months, ending 30th June 1946, the consumption in Britain, on available supplies, of 'Margarine, Lard, etc.', for which vegetable oils are the chief raw materials, decreased by 129·2 thousand tons, as compared with the previous twelve months, according to the official *Monthly Digest of Statistics*. In face of this, and since the housing drive was also being delayed by shortage of linseed oil for paint, the Government was forced to purchase large quantities of vegetable oil, mainly linseed and sunflower, from Argentina, at a price, reputed to be £135 per ton, more than double their estimate. In addition to this they purchased 360,000 tons of linseed cake and 180,000 tons of sunflower cake, also from Argentina, to maintain our dwindling livestock, at a figure which Mr. R. S. Hudson, formerly Minister of Agriculture, estimated as being £6,000,000 in excess of what this purchase could have been made at on the open market.

When the total cost to the nation, much of which will have to be covered by subsidies, recouped by indirect taxation, has to be computed, there must be added to the actual purchase price not only the overhead expenses of the purchasing commission in the Argentine, during a prolonged series of negotiations, but the colossal 'invisible' expenditure involved in any deal handled by a government department, ruled as usual by red tape routine.

This staggering example of Government trading is undoubtedly the result of a policy of refusal to encourage the growing at home of these two crops or to offer a fraction of their value to their home producers. This policy has created just that 'artificial scarcity' which Mr. Atlee rightly disparaged, when outlining his government's policy on 5th June 1945.

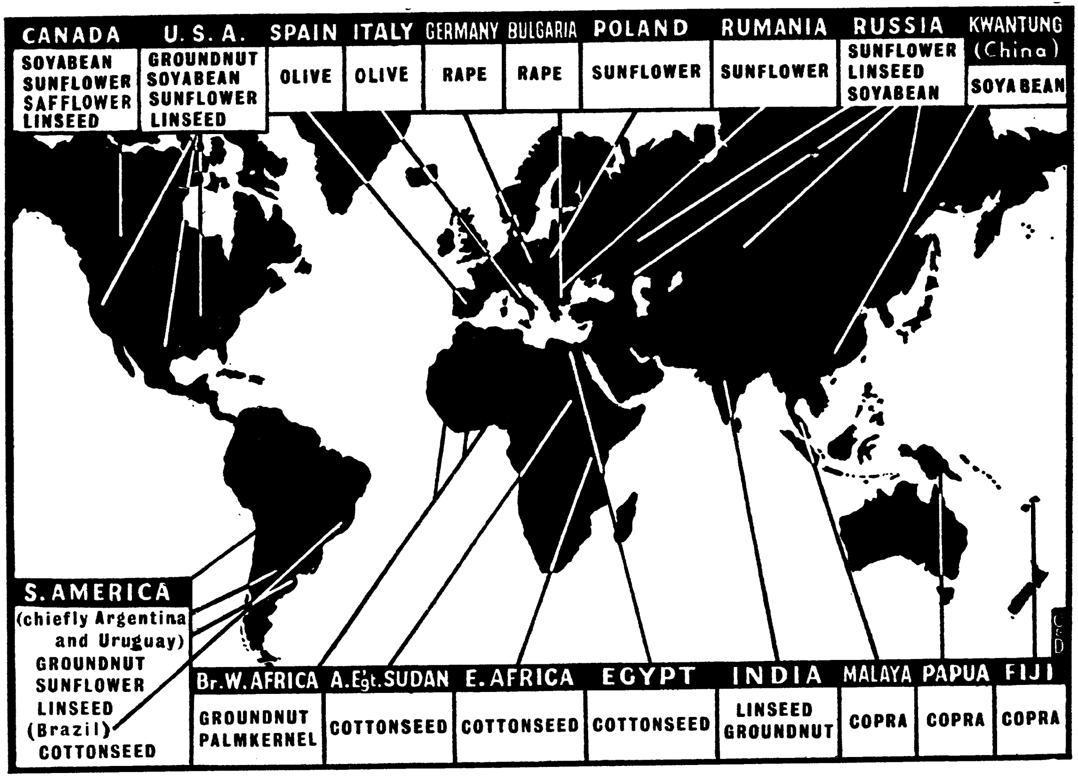


FIGURE 1.—The main vegetable-oil-producing areas—pre-1940—and their principal oil crops.

PART I

CHAPTER I

THE IMPORTANCE OF EDIBLE OILS

'My own feeling is that we should grant to every man, woman and child the right to have enough milk and butter . . . enough of the protective foods of all kinds so that everyone can be fit to do his part in the world of to-morrow.'—SIR JOHN ORR.

One of the predisposing causes of war is want—lack of food and under-nutrition, whether following shortage of food or due to an ill-balanced diet. The former causes ill health, high mortality and unrest. The latter is a predisposing cause of disease, brings about general unfitness and reduces the stamina of a nation.

As time goes on most peoples tend to increase their daily consumption of fats and oils—butter, margarine or vegetable oil—and it seems likely that, given sufficient supplies, 20 per cent to 30 per cent of human energy could be derived from these sources alone. The fats and oils yield far greater energy, weight for weight, than do cereals, bread and lean meat. When we consider those countries which, in pre-war times, consumed the largest proportion of such fats we find that they are the most prosperous in that their output of work per man is highest. We have only to compare the work output and prosperity of the cereal eating nations, particularly China and parts of India, with such countries as U.S.A., Britain, Belgium, etc.[1]

The primary function of carbon- and hydrogen-containing food, such as vegetable oils, is, by its combustion, to produce heat or other forms of energy. Since fats contain about two and a half times the proportion of carbon as do sugar and starch, they are the most concentrated form in which heat and energy-producing food can be supplied to the body. Since man's stomach is smaller than that of most animals the use of these highly concentrated forms of carbon food becomes all the more important. Some carbohydrates, i.e. glucose, are readily assimilated and some fats are assimilated with difficulty especially as they have a melting point above body temperature, but they render other forms of food more palatable and assist in their digestion.

[1] See 'Hot Springs and Humanity' Le Gros Clark—*Discovery*, July 1943.

Both the climate and availability determine the average relative proportions of fat and carbohydrate in the diet of different races. Thus the Indians and Chinese, living in hot regions where carbohydrates predominate, subsist mainly on these while the Eskimo likes most of his carbon in the form of oils and fats. On the average, in a temperate climate, physiologists tend to recommend one part of fat to ten of carbohydrate, with some increase of the former in winter.

Butter is the most easily digestible of all fatty foods. Margarine, as now generally constituted, largely from vegetable oils, is generally agreed to be equally digestible.

Edible oils and fats are oxidized after absorption into the body and the resulting energy converted into heat or performance of work. This action is accelerated by the salts of the bile acids.

But, apart from consumption of vegetable oils, whether extracted from palm-nut, ground nut, soya bean, maize, olive or sunflower, in their pure state or as substitutes for butter and lard, there must also be taken into consideration the by-products, also rich in these same oils, which, fed to livestock, produce the animal fats found in meat and milk.

To trace the sources of vegetable oils is too lengthy a subject for this book, though mainly they have come from the warmer climates—Africa, South America, the Pacific, etc. Nor is it possible here to trace their distribution among the different nations. The European countries and also North America, becoming more and more industrialized and with increasing populations, have long found their own sources insufficient and therefore reached out to acquire other sources of supply. Aided by their prosperous industrialism and export trade these countries were able to obtain the major share of the world production. Some of these oils were used for industrial purposes, as well as for food and feeding stuffs, but the use of the edible oils for such purposes has tended to decline. Due to the above causes and the enormous increase in the output of margarine, particularly in Europe, even by 1936 the producing countries were exporting three and a quarter million tons annually, of which about two-thirds came from Asia. Of this export more than three million tons was distributed over western Europe and North America, with some to Japan.[1]

The Asiatic and African continents were producing more than half the world's annual output and exporting half that production. What this actually means is that 40 per cent of the world's population was consuming 75 per cent of the world's edible oil production. Looked at in reverse we can see that this means that 60 per cent of the people of the world

[1] See 'Hot Springs and Humanity' Le Gros Clark—*Discovery*, July 1943.

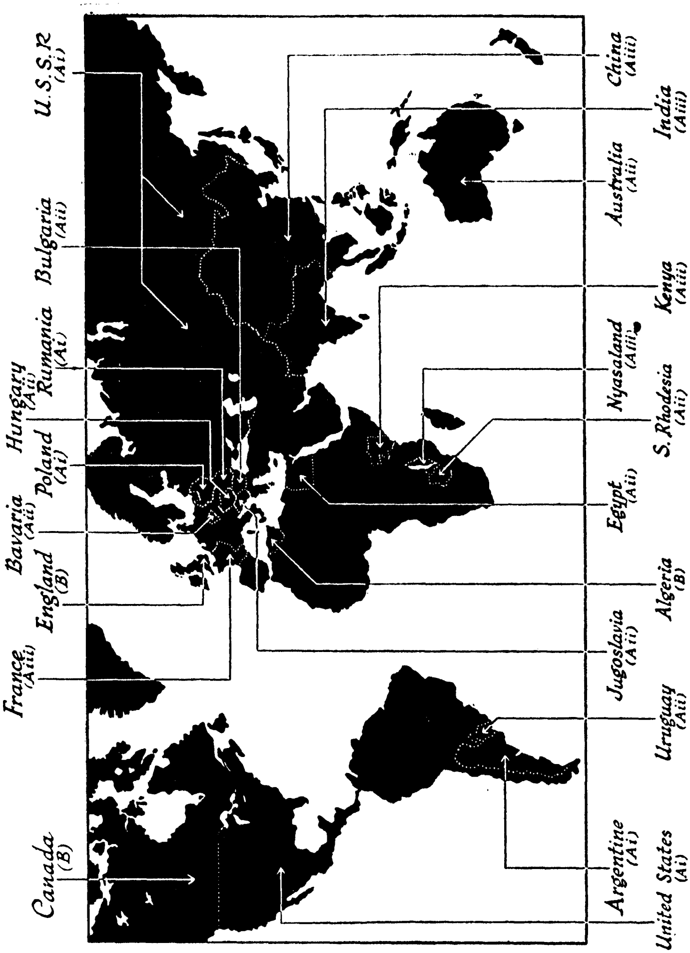


FIGURE 2

Map showing countries where sunflower is or has been successfully grown, either for export or internal consumption. Figures after country name indicate as follows:

Ai. Large producer previous to 1939.
Aii. Large grower before 1939, but less important than Ai class.
Aiii. Sunflower grown on moderate scale or in certain areas.
B. Growing since 1939.

were trying to maintain a healthy life on a very small proportion of the world supply, although they themselves were actually the producers of most of it.

IMPACT OF WAR 1939

As far as Britain is concerned the outbreak of war had serious consequences. First the shipping situation cut off much of our African supplies. This, of course, made itself felt not only in the production of margarine but also in feeding stuffs for our cattle which, through their milk, gave us normally another source of fat, in butter. We had also been accustomed to receiving £13 million of butter from Denmark (1938 Board of Trade returns) as well as some £10 million from Finland, Latvia, Lithuania, Poland, Estonia and Holland. The occupation of these countries deprived us of this supply. Apart from butter, our pre-war imports of vegetable oils, oil seeds and oil seed products (excluding castor bean and those seeds used for the production of gums and resins) reached a vast figure. The following are taken from the Board of Trade returns for 1938, the last year for which full returns are available:

	Tons	£
Seeds—oil	1,591,016	14,303,162
Oil—vegetable	214,215	4,123,658
Feeding cakes	665,428	3,894,939
	2,470,659	22,321,759

The previous year, 1937, showed even greater imports, the reduction in 1938 being largely bound up with the Spanish Civil War and its results on Argentine exports, the Sino-Japanese war and the uneasy period in Europe. The Argentine has been a producer of Sunflower for nearly a century and was the main source of supply for sunflower feeding cakes for the Danish dairy industry. But the cutting off, by the civil war, of supplies of olive oil from Spain, caused the Argentine to step up her ground nut and sunflower acreage in order to fulfil her own needs.

In the 1938 import figures above 72,000 tons is accounted for by copra, largely from Malaya, Fiji and Papua. With the Japanese entry into the war against the Allies most of our Far Eastern supplies of edible oils were cut off. While soya bean was not a very large proportion of our imports the greater part of this had previously come from the East, especially from China (Kwantung peninsula). It will therefore be easily understood why, from early in the war, we had to ration butter and

margarine and why, with the lack of oilseed feeding cakes, our own milk and beef production rapidly declined. The production of eggs was also curtailed for lack of grain, though we know now that sunflower would have provided an advantageous substitute.

As, up to the present, only two oilseed crops have been found that we can grow economically in this country, linseed and sunflower, the former of which does not produce an edible oil, the above figures and facts will show the vast field that can be covered by sunflower as a home-grown crop.

But reference to the facts given in the above section will show that the U.S.A. and Canada, among the United Nations, being also among the largest importers of vegetable oils, were also badly hit. While in the warmer climates of the Argentine and the southern U.S.A. groundnut was a crop which could soon make up some leeway, for many reasons it was found that sunflower was a better crop and was, of course, essential for climatic reasons to Canada.

Some particulars of the world expansion of this crop will be found in Chapter III and particulars of the war-time and later extension in many countries in Chapter XI.

VALUE OF OILS AND FATS

Apart from their energy value, as set out at the commencement of this chapter, most fats and oils are rich in vitamins. Butter is a most important source of vitamin A and, particularly in winter, butter from stock fed on oilseed cakes contains four or five times as much of this vitamin as that from cows fed on ordinary hay. It is vitamin A which creates resistance to winter diseases, particularly in children.

Animal fats, such as meat or those derivatives of animals, butter, milk and cheese and even eggs, are essential to a balanced diet, more especially for their vitamin content. But while fats and oils obtainable from land and marine animals are limited in quantity, such is not the case with those of vegetable origin where propagation of crops is more under man's control and, further, the use of such crops or their by-products, especially those with an additional protein value, is a rich source of feeding stuffs for the direct increase of animal fats from domestic stock.

Margarines vary in vitamin content in accordance with whether they are produced from nuts, such as coconut, groundnut or other vegetable oils, or from animal fats, including whale oil. While dairy butter is rich in vitamin A, as well as D, whale oil contains vitamin A, but no D. And when hydrogenated to remove odour and for conversion to a solid fat, such as margarine or shortening, all oils, including whale oil, lose

all vitamin A as also vitamin D if present, though vitamin D can be added artificially. Vitamin D is of course the preventative of rickets.

Probably vitamins are higher in those vegetable fats from oilseeds than from groundnut. By the summer of 1940 we had reached a stage where only 20 per cent of our energy was obtained from fats as against 35 per cent in the pre-war years. None of the oil nuts contain much vitamin A but are mostly rich in vitamins B_1 and B_2. B_1 is largely present in wholemeal bread.

Of the average daily requirement of 5,000 units of vitamin A, the adult in pre-war years obtained about half from dairy produce as also probably a large part of the necessary vitamin D.

The B vitamins are necessary for the complete utilization of carbohydrates in the human body and children in particular need substantial daily quantities. These have considerable effect on the nervous system as well as on digestion and appetite. About a quarter of this requirement comes from dairy produce with about a fifth from meat and eggs, though shortage of the latter foods can be compensated for by the use of wholemeal flour. On the other hand a pint of milk per day will provide about one-third of the average daily requirements of vitamin B_1 for an adult.[1] From this again it will be seen how essential it is that the country's milk supply should be maintained and for this, in winter, we must again fall back largely on oilseed feeding cakes. Sunflower seed is an important source of these B vitamins (see p. 156).

The vitamins A, D, and E are what are known as fat soluble. Considerable investigation still remains to be made on the question of vitamins in vegetable oils, including sunflower oil. Although vitamin A is synthesized in green plants having light absorbing systems of the chlorophyll type there is usually only a small amount in the seed and then only in the embryo. While the amount of vitamin A to be found in milk is dependent on the amount present in the fodder fed to the cattle, if only the supply of oilseed cakes is sufficiently increased to allow the dairy herds to be increased and maintained during winter we have an additional supply of dairy products which will be a source of this vitamin when and where a vitamin A-containing fodder is fed. In regard to A, rape and cotton seed oils contain none, olive oil only a trace, poppy and sunflower oils contain up to 1,200 units. On the other hand many plant oils contain carotin, convertible into vitamin A in the animal body. Even if the content of vitamin A in sunflower oil should prove negligible, since by irradiation all oils and fats used for margarines can be artificially supplied with this vitamin, the importance of sunflower oil

[1] See *Food the Deciding Factor*, Frank Wokes, Ph.D.(Lon.), B.Sc.

for increasing our supplies of margarine becomes apparent, since it is an additional vector for supplies of this vitamin. In just the same way vitamin D can be added to fatty foods by irradiation. And four ounces of margarine thus irradiated provides the complete daily need of vitamin D to a single adult.

Investigation tends to show that, as yet, no vitamin D has been found in any plant products.[1] Sunflower, however, contains a rich store of the fertility vitamin E.

On balance, therefore, it will be seen that where vegetable oils do not provide a direct source of supply of certain vitamins their increased production and usage can form a very valuable secondary aid to an increasing supply of these, either by increasing other direct sources of supply or by acting as vehicles for irradiated vitamins.

According to the *Financial Times* of Canada (4th August 1944) the Canadian Fats and Oils Administrator stated that the processing of sunflower, as well as rape seed, soybeans and flax, had to be considered as a primary factor in the increase of oil-bearing crops in the Dominion and that prairie processing plants must be erected close to the fields of production to provide convenient markets for the growers. The Administrator also pointed out that the by-products of these crops would go far toward solving Canada's stock feed shortage in future years. These crops are looked on as essential vitamin suppliers.

'HOT SPRINGS'

Clause 4 of the Atlantic Charter proclaimed the right of all peoples to 'the raw materials of the world which are needed for their economic prosperity'. This was the basis of one of the 'Four Freedoms'—Freedom from Want.

The conference held at Hot Springs was called to discuss the problems of World Food Distribution and Production after the war and to lay a basis for an even spread-over of the World's foods, to ensure adequate nutrition of all peoples and 'freedom from want'. That the distribution in the past has been inequitable, particularly in oils and fats, is clear, and considerable thought has been given as to the first essential steps to be taken. Which policy should be pursued? Should an attempt be made first to even out distribution or shall we leave things as they are and essay to assist the agriculturally backward peoples to develop their production, more especially of essential foods?

All meat, butter and fruit exporting countries, with the exception of

[1] *Chemistry and Physiology of the Vitamins*, Rosenberg (New York 1942).

the U.S.A., have small populations though some have a high consumption of the foodstuffs which they export. On the other hand many countries with high exports and production of essential foods consume little of these, far less in fact than is essential for their own well-being. This is largely due either to a desire for monetary gain or to exploitation. In the case of vegetable oils it has already been pointed out that the lowest consumption has been in the producing countries, and these are the countries that are most backward in civilization and largely too in health, physique and prosperity—in fact below the desirable average standard of living.

Now, if the findings of 'Hot Springs' mean anything—and we cannot imagine that this is a colossal international bluff—then this ironing-out of the world's foodstuffs is due to take place, if only as one means of removing a source of future wars. Some beg the question by saying that the sole cause of war has been a desire of aggression, overlooking that aggression has always as a basic motive the desire to obtain necessary raw materials and, more than anything else, additional food supplies.

A huge proportion of the world exports of all foodstuffs has been previously diverted to about 7 per cent of the world's consumers. It therefore appears that there should be no reasonable bar to more even world distribution. This means competition for existing production, where little competition existed before 1939. There is no place here to go into the economic reasons why food-producing countries export what they should consume, as this is bound up with the supply and demand for other raw materials.

While more equitable distribution will mean a rearrangement of the agricultural economy of many countries it will from many points of view be all to the good. The very fact that Britain tended to import more and more meat from abroad and more and more butter has reduced her own herds and, by so doing, impoverished her soil through the lack of natural dung and the essential humus for high production of foods that also have the highest feeding value. The tendency to monocultures such as rice, sugar and bananas, in Burma, Cuba and Jamaica, has created an unwholesome agricultural economy in those countries which cannot but finally lead to disaster. But few countries have a true surplus food export though even in some of those the standard of diet of the poorer classes leaves much to be desired. Many countries can and still more must depend on producing almost all the essential foods needed for their own population. This leads us to consider the post-war position of Britain as against world trade and world conditions.

POST-WAR POSITION

While we admit that export trade for an industrial country, such as ours, is desirable and to a great extent essential, we must visualize that food is the only essential of life and must come first. Further we must agree that our average nutritional standard had, before the war, a long way to go to be brought to its proper level. Rationing and Lend-Lease raised that standard to a very good average during the war, though that standard is far below what we would wish to maintain in peace-time. We do not wish rationing to go on indefinitely and we cannot depend on Lease-Lend after the war.

But, if we examine the changes wrought by war conditions on the industrial capacity of most countries, we must easily realize that a return to pre-war export trade is only a beautiful dream. On our export trade and the credits thereby created we were able to purchase abroad and import almost all that we desired and a great portion of those imports were foodstuffs. Australia and New Zealand sent us butter and mutton in return for manufactured goods, machinery, boots, clothes and so forth. This happened with many countries, but particularly with our Colonies and Dominions. But the stress of war, the widening of the conflict and, more especially, enemy occupations and shipping shortage, turned all these countries into industrial producers, not only for their own population but also for their armies and those of their allies overseas. Australia and Canada, South Africa and India have become almost self-supporting. It is sheer madness to imagine that these countries will demolish their factories and dismiss their skilled operatives in order to provide anew the export trade of a boot manufacturer in Northampton or a cotton spinner in Lancashire.

Yet, if we are to depend on imports for our foods, we must have corresponding exports. Reduced exports therefore mean reduced imports and the answer, as far as food is concerned, is increased home production. It is therefore necessary to select not only the most economical crops to grow in Britain but also what new crops we can introduce to take the place of previous imports.[1]

[1] What the writer has written above, and frequently stated both in public and in the Press, has since been substantiated by Mr. Hudson, Minister of Agriculture, who, speaking in London, 1st November 1944, said: 'One of the difficulties facing agriculture to-day is the existence of many people, to whom it seems that there is an antithesis between our export industries and home food production. But I believe . . . it is vital to the future prosperity of our country that the two should march forward hand in hand.... Exports are not, as some people tend to think, an aim in themselves. They are a means to an

The 'cheap food' policy is a bogey. The food we imported before the war has seemed cheap on actual purchasing values but, if a balance sheet is struck, with, on the debit side, the large sums we have invested in the Dominions, the Argentine, etc., as capital to develop their agriculture and provide transport, many of which had even ceased to bear interest, it will be found that we have paid more for that food than if we had produced it ourselves. In addition to these debits we might well add the enormous shipping losses we have sustained during the two world wars in an effort to provide food for our people, much of which should have

end that is to enable us to import the things which we need. For a time, at any rate, the resources put at our command by our exports are unlikely to cover everything we require. . . . We shall have to cut down on other things than necessities. We want both food and raw materials. *But many of the raw materials we most require we cannot produce here at home, whereas the* farmer and farm worker in this country have shown that much of the food we need can be grown here. *If therefore we must economize, it seems only sensible to do so on imports of food.* Our soil is not suited to the production of all we need of certain commodities. . . . We do not wish to maintain any longer than we need the terrific acreages of wheat and potatoes that we are at present growing. For some time our overseas income will be limited and will not enable us to import all that we should like to. So long as it is limited *we must concentrate on importing those essentials that we cannot produce here*. Agriculture can make an important contribution by enabling us to economize for the time being on food imports. In due course, as our overseas financial resources are increased and as our standard of living rises, I believe that we shall be able to absorb not only the food which countries overseas wish to send us but also the food which a healthy and well balanced agriculture in this country should produce. . . . It is true that farming systems which exploit the soil are laying up great trouble and expense for the future.' Mr. Hudson added a further reminder that the Hot Springs decision was that *each country must do its best to raise as rapidly as possible the nutritional standard of its people*, and stated that our post-war difficulties could be overcome on certain conditions. 'The first is that we make use to the greatest possible extent of our own natural resources at home . . . the land.'

A most important part in this speech was Mr. Hudson's statement on a point which has been too little brought before the public in recent years: that other countries had now built up their own economies and were challenging British supremacy in international trade. Countries that were predominantly agricultural had built their own secondary industries. 'One most important post-war change will be that from a creditor nation to a debtor nation—able no longer to rely on the accumulated wealth built up in the past overseas.' He said there would have to be greater concentration on the things required at home rather than on products for export and that, against this, if primary producers got more for their products they would have more money with which to buy home-produced industrial goods so that the market for these would be increased.

been home produced. This figure alone probably exceeds the cost of the whole of our food purchases over a period of twenty years!

Much of our 'cheap' imported food resulted from under-paid labour abroad and a miserably low standard of living in the producing countries. As Mr. Hudson pointed out in the House of Commons on 19th November 1941, cheap food had depressed our agriculture and meant sweated labour and sweated land in the producing countries overseas. The final decline of our pre-war agriculture started with the 'Large *v.* Small Loaf' election of 1906.

PROBLEM OF EUROPE'S AGRICULTURE

The agricultural reconstruction of Europe is a long-term major problem as is building up the health of these starved nations. These are factors which impinge heavily on our own agricultural and food position. For several years Europe has been farmed entirely for the German Reich. This means that where, in pre-war years, any one country may have been more or less self-contained in agricultural production for its own needs —a kind of small holding, let us say—Germany has viewed these countries, in many cases, merely as a single field in a European farm, so that many of them have become almost mono-agricultural. To revert to national economy means entire replanning. But, when the problem is complicated by the fact that for years these lands have been 'milked', denuded both of artificial and, more especially, of natural fertilizer and even many of their peasant owners deported or killed, it will be understood that it will take many years to bring order out of chaos. During those years Europe will have to be fed largely from outside. This means that what food has been spread, with the aid of rationing, over the free nations during the past four years, will have to be further divided with Europe.

One of the greatest shortages in Nazi Europe has been in fats and oils and although, before the war, certain quantities of oil seeds, especially sunflower in the Balkans (as well as, of course, olive oil in Italy and Spain), were produced, western Europe was mainly dependent on supplies from overseas. It will therefore be seen that, with the reconstruction of nutrition in Europe, added to the more even world distribution envisaged by Hot Springs, our own pre-war position in regard to these very essential food and feeding stuffs will be severely worsened.

EDIBLE OILS IN GERMANY

The following is quoted from an account of the position in regard to

edible vegetable oils and fats in Germany, in the *Kölnische Zeitung* during 1944. 'Even before the advent of National Socialism the problem of fat supply was one of the most critical problems of German foreign trade policy in as much as the gap between home production and consumption was continuously increasing.

'During the battle of production of recent years, however, we have succeeded in raising from our own soils oil and fats, both by the increase of milk and fat yield of dairy cattle and by the cultivation of oleaginous plants.

'At the outbreak of war Germany's demand for edible fats of animal and plant origin aggregated about 1,200,000 tons.... As much as 92 per cent of imports were of vegetable origin.

'The size of the imports shows the magnitude of the task with which German agriculture was suddenly faced.... In planning for 1944–5 the Reich Food Estate will again have to devote exceptional efforts to increase still further the cultivation of oleaginous plants because, of all methods of fat production, the cultivation of rape seed is the most fruitful.'

EUROPE'S FUTURE

Speaking of post-war Europe, Yates and Warriner[1] point out that the impact of the outside world on European farming will be felt immediately any post-war relief schemes begin to come into operation, and will at once raise important problems of adjustment. The Nazis have only been able to secure self-sufficiency in Europe in bread supplies—at a very low level. They have not been able to grow fodder, so that livestock, the farmer's capital, has been cut down. Crop production was drastically cut through innumerable causes and the occupied countries had little surplus for Germany. The reconstructed countries must intensify their production for home consumption, largely stock farming and horticulture.

The obligations under points three, four and five of the Atlantic Charter apply particularly to the peasantries of the world. On the one hand the obligation lies on the Governments of each country to foster the well-being of the farming communities so that the gap between factory worker and the land is significantly reduced or completely closed. Secondly there is the obligation of the wealthier nations to raise the standard of living of the backward, principally peasant, countries. This means levelling-up. Obligation 'one' is the work of at least a generation

[1] *Food and Farming in Post-War Europe*, Yates and Warriner.

and it envisages restriction on the export of foodstuffs, wheat or other produce, from those countries whose standard of living has been far too low, whether in Europe, India or many of our own Colonies.

The world surplus is wheat but it needs more even distribution. The world shortage lies in vegetable oils and this entails not only even distribution but greatly increased production.

The terrible shortage of dairy cattle in Europe must be overcome. This means that the peasants will require imported oilcakes for, since they will have to grow more market garden produce, to feed the growing industrial populations, and more fodder, they still will not be able to grow all the oil seeds needed. More land will have to go down to pasture. Prosperity introduced into farming in these countries means more food consumed by the peasantry where previously they had to sell their produce to keep body and soul together, living in a state of semi-starvation.

Peasant welfare is no small concept. It involves nothing less than an onslaught on the abject poverty of two-thirds of the population of this planet.

BRITISH OILSEED CROP POLICY AND POSSIBILITIES

It was due to this long-term view, knowing that vegetable oils were the greatest world shortage,[1] that increasing attention was given to the possibilities of oil seed crops in this country, both by the Ministry of Food and the Ministry of Agriculture. How far this policy is being put into effect is one of the matters which this book will explain.

During the past few years considerable attention has been given to soya bean and sunflower for the production of oils suitable for human consumption. Soya bean, in spite of its many uses, is of course a natural product of hot climates and while considerable experiments have been made with this crop here and suitable varieties have been found, its future is problematical. This is largely due to the fact that, on the one hand, even the 'suitable' varieties are only suitable under exceptional seasonal conditions. On the other hand even under best conditions soya has been found to be a very shy crop, shy that is in that, under exactly similar conditions, one crop may succeed and another fail. It is also a crop which, especially in our climate, seems very liable to virus disease. Soya too yields a comparatively small crop of oil bean to the acre.

Sunflower on the other hand is indigenous to many countries and so far from being a hot climate crop has been shown to be adaptable, provided the most suitable varieties are chosen, to almost any climate. In

[1] See statements in Parliament by the Minister of Agriculture, Mr. Hudson.

fact, to take extremes, successful crops have been grown in Norway and again in Central Australia. From the point of view of soils too sunflower is not particular and there are very few fertile soils in which it will not give a handsome yield, whether heavy clay or even the alkaline sands of California, where considerable quantities are grown.

In fact throughout the writer has pointed out that, since sunflower has been a native of our gardens from Land's End to John o' Groats, there was no reason why any difficulty should have been found in growing it here and, knowing this, it has long been a blind policy—possibly due to tradition—which allowed us to buy butter from Denmark, when we were aware that sunflower cake formed so large a part of the concentrated ration of their dairy herds. Had we introduced sunflower as a staple crop in this country, as it has been for so many generations elsewhere, we should have been almost self-supporting in the war years for milk, butter and eggs. The benefit would have been: (1) we should have saved shipping and lives; (2) we should have had more of the essential health protection foods, and those in fresh condition; and (3) we should have been able to maintain, if not increase, our herds of cattle and our flocks of poultry to the ultimate benefit of the fertility of our soil.

(*a*) In 1943 the British Government contracted to buy all the Argentine's exports of eggs.

(*b*) In 1944 the British and U.S. Governments contracted to take over the Argentine surplus of sunflower seed oil.

(*c*) The Minister of Agriculture stated on 20th February 1944: 'Agriculture's burden cannot be lightened by victory in Europe. Plenty cannot return for many years after we have made the Nazis bite the dust. The stricken people of Europe are crying for food. We and our Allies must give it to them.'

U.S. AND CANADIAN 'POST-WAR' STATEMENTS

Captain L. D. Gammans, M.P., on his return from the U.S., where he had talks on post-war international trade, stated in May 1944 that the U.S.A. had, as a result of war industries, become almost a self-sufficing country, with the consequence that its future export trade would be severely curtailed since there was little it needed to import from the very countries in which it might otherwise find the largest export market for its goods. Actually a similar decision had been arrived at in consultation between experts of the U.S. and Great Britain in 1941, though what they said then boiled down to the fact that, as far as export from Great Britain to the U.S. was concerned, the latter would need practically

nothing from us beyond whisky, Rolls Royce cars and pedigree livestock. All these possible requirements were qualified. The whisky depended on whether we could spare the land to grow the necessary barley; the American market for Rolls Royces depended on whether the British aristocracy could afford to run them, since otherwise the American snobocracy would not be interested; and in view of the reduction of most of our herds and also our own acknowledged 2,000,000 shortage of dairy cattle, it is very doubtful if we shall have much pedigree stock to sell abroad for many years to come.

All exports, as Captain Gammans has pointed out, are really a loss to the consumers of this country and should only be exported if in return we are enabled to import something we badly need which we cannot produce ourselves. Thus the difference between 'need' and 'want' must be borne in mind. It is true that with our population, in spite of what agriculture has shown that it can do towards feeding Britain, we must import some foodstuffs. It therefore remains to find what we 'need' and to discard what we merely 'want' to import. The first thing therefore is to decide that we must produce what we can grow economically in this country and, if we can produce our own oil seeds we should concentrate our imports on the protective hot climate fruits and certain cereals, such as rice and tapioca, and especially a large quantity of grain which can be more economically grown abroad—grain of a better standard than we produce here to fill the demand, even if not a sound demand, for white bread. In other words we must base our imports on a basic minimum. We must bear in mind that our soil is as good as any in the world and that that is our main capital, which must be maintained. To rob our soil is to reduce our capital, whether the robbery comes about by forcing uneconomical crops by means of artificial inorganic fertilizers or by importing vast quantities of meat when cattle would feed our soil.

Before the war we imported roughly £20 worth of food and raw material per head of the population of which £6 worth had to be paid for by our invisible exports—largely overseas investments most of which no longer exist, having been liquidated before the U.S. accepted us on the 'cash and carry' basis. Captain Gammans rightly points this out but adds that this fact plus the reduction in the value of money means that we must double our post-war exports. But this seems impossible since our Dominions have been industrialized, for surely we cannot force them to take our goods at the expense of their own industries. To say that by not buying so much mutton from New Zealand or sugar from the West Indies we are upsetting their economy seems to be begging the question, since the very industrialization of these countries will, as has happened

elsewhere, cause them to reconstruct their own economy in the agricultural field.

The fact that the Ministry of Food envisages some degree of rationing for at least five years after the war seems to show that the more we concentrate on home food production the better. As for exports, we must struggle to provide these in new markets as far as possible and concentrate on new industries to provide goods for home consumption, rather than depend on imports of raw materials to be re-exported as manufactured goods (which, to say the least of it, in shipping alone, is not good economics, from the point of view of the ultimate consumer wherever he may be). That cotton should be produced in the East and re-exported, when manufactured in Britain, to the East is about as uneconomical to the consumer as is the taking of vegetables from Lincolnshire to Covent Garden to be redistributed to the Midlands.

There must be complete dismissal everywhere of concentration on 'money' crops to the detriment of subsistence crops as the former leads to mono-culture and lowered standard of living.

Mr. J. A. Mackinnon, Canadian Minister of Trade and Commerce, said on 17th May 1944, when speaking of the necessity for finding the greatest possible outlet for Canadian products of agriculture and industry in Britain, 'Our post-war objective must be to do everything in our power to restore a world in which markets in all quarters of the globe will be open to the Canadian exporter on a good competitive basis. In the seven years before the war Britain was the greatest single buyer of Canadian goods. This is comfortable history—*but what of the future? Britain's exports will have fallen to a low level, her shipping earnings will be reduced and her income from foreign investments will be away down.* Canada must look ahead to what will happen when she may lose this sheet anchor of her foreign trade.'

Consideration of the above statements only goes to show that, whatever our manufacturers may hope for, unless they can greatly reorganize, there is no illusion abroad as to the amount of our future exports. Without exports credits for imports cannot exist. The wise general looks ahead and, when he foresees the possibility of a siege, discards the expectation of and dependence on outside assistance and either lays in stores of food or, as we have done in the past four years, sets about seeing what he can produce on the spot.

CHAPTER II

THE UTILIZATION OF SUNFLOWER

In his 'pep' speech to the German people, in October, 1942, Goering promised them more fats for the coming winter from the Sunflower of the conquered Russian Territory.

FORAGE

In many countries sunflower has been and still is grown as a forage crop. Forage crops are either fed green to cattle or are preserved as ensilage. But, for forage, while sowing can be done broadcast, to ensure the utmost ground coverage and greatest amount of foliage, the crop must be cut before seed ripens, while the stem and leaves are tender and contain the minimum amount of indigestible fibre. In America silage is made from sunflower but it is doubtful if it is an economical forage crop in those climates or soils where more succulent forage can be grown.

EDIBLE OIL

In all countries where sunflower is grown, whether the large producing areas such as Russia, Roumania and the Argentine or the somewhat smaller areas of the U.S., Canada, Uruguay, Hungary, Rhodesia, etc., the main object is seed for the production of edible oil. For human consumption sunflower oil is equal to the finest olive oil both for feeding value, lack of taste, colour and keeping qualities. In fact it has the advantage over olive oil in that it remains liquid at a lower temperature. For margarine it is probably in the top rank; for salad oil, cooking and frying, canning and medicinal purposes it has the highest qualities. Whereas the olive tree needs some eight years to attain economic maturity the sunflower is a rapid-growing annual, reproducing itself a thousandfold, which can follow in any farm rotation. The oil in the seeds amounts to from 32 per cent to 45 per cent. It is largely used in place of olive oil or lard for cooking on the Continent.

The value of an oil depends largely on its constitution as well as the purpose for which it is required. Its suitability for a particular purpose depends too on its titre or solidifying point and this is particularly important when we are considering oils used in the manufacture of margarines and vegetable lards, which to-day probably constitutes the largest outlet for the edible vegetable oils.

All vegetable oils are mixtures of the glycerides of several fatty acids and these not only regulate the melting point of a particular oil but also the particular proportions of such glycerides determines the pe-

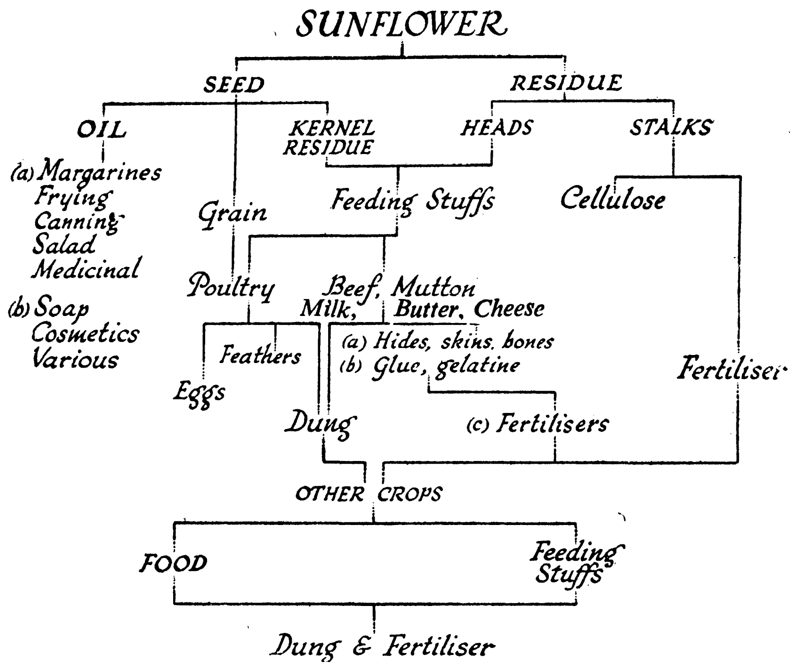


FIGURE 3

Resultant Savings—shipping; exports required for other foreign purchases; health; land fertility.

For every million head of cattle slaughtered abroad, of which the products are imported into Britain, we lose 160,000 tons of dung and much residual fertilizer of an organic nature. For every million pounds of butter we import we lose 2,000 tons of dung. The same loss applies to imported mutton, eggs and all dairy products. And thereby we decrease the fertility of our land—our capital; produce fewer and less nourishing crops, use more shipping space and more exports for the importation of fertilizers, many of which are inorganic and detract rather than add to our fertility.

culiarity of the same. Sunflower oil consists mainly of the glycerides of oleic, linolic and palmitic acids with a small amount of linolenic acid. It is this latter which gives it a valuable drying property when employed for

paints. Generally it is classed as a semi-drying oil, being less pronounced in this property than hemp and poppy oils.

Refined, first grade sunflower seed oil, freshly obtained, is a pale yellow fluid with a pleasant odour and flavour, though second pressings usually retained for manufacturing purposes, are of a darker colour.

From the feeding and medicinal point of view it is, for most purposes, fully equal to olive oil and has the advantage of having a lower titre or solidifying point (17–18° C.) than olive oil (21° C.) though its semi-drying properties allows a film to form on the surface when exposed to air, a drawback from which the non-drying oils are free.

The following figures relate to a typical example of sunflower oil:

Specific Gravity at 15° C.	*Saponification Value*[1]	*Iodine Value*[2]	*Acidity (as oleic acid)*	*Titre*
0·9259	191	126·2	0·81	17° C.

Comparisons with some other oils are as follows:

	Specific Gravity at 15° C.	*Saponification Value*	*Iodine Value*	*Titre*
Shea Butter	0·917	178–189	56–65	52·5° C.
Shea Oleine		181·6	62·3	
Hazel Nut Oil	0·917	190–197	84–90	19–20° C.
Olive Oil (Ital.)	0·9120	190·6	84·4	
Olive Oil (Span.)	0·9116	192·4	83·7	
Olive Oil (Calif.)	0·9119	190·6	85·1	
Olive Oil (Tunis)	0·9131	193·6	86·0	
Palm Oil	0·9209–250	196–205	48–60	38–47° C.
Palm Kernel Oil	0·873	244–255	16–23	
Coconut Oil	0·926	251–263	8–9·6	20·4° C.
Coconut Stearine		251–259	3·8–7	
Coconut Oleine		257–265	13–15	8·13° C.
Peanut Oil (Virginia)	0·9128	186–187	89–96	30-31° C.
Peanut Oil (Span.)	0·9138	187–188	90–94	30-32° C.
Corn (Maize) Oil*	0·921	189–191	124–126	

* *Refined.*

[1] Saponification value (Koettstorfer Number) represents the number of milligrams of potassium hydroxide required to saponify one gram of fat or oil.

[2] Iodine Number (or Value) represents the number of grams of iodine absorbed by 100 grams of fat or oil. This classifies the oil, i.e. below 100, non-drying oils; 100-130, semi-drying oils; over 130, drying oils.

	Specific Gravity at 15° C.	*Saponification Value*	*Iodine Value*	*Titre*
Cottonseed Oil*	0·915–26	191–198	103–115	
Rape Oil*	0·9147	172–4	91·6	
Sesame Oil	0·920–26	188–193	102–10	
Linseed Oil†	0·921–38	189–196	170–204	19-21° C.
Soy Bean Oil	0·922–25	189–194	103–136	

* *Refined.* † *Expressed.*

From the analytic point of view of the fatty acids in sunflower seed oil, figures vary considerably both with variety and country of origin. Bauer's work in regard to oil from the ripening sunflower seed showed that the oleic acid content rose steadily throughout the ripening process while saturated oils correspondingly decreased, the iodine value remaining constant.

The melting point of the fatty acids in sunflower is 22°–24° C.[1]

COMMERCIAL OIL

Apart from its edible properties sunflower seed oil has many commercial uses, such as fine paints, soaps and cosmetics. In some parts of the Continent it is reputed to be the most suitable oil for the treatment of shoddy in the woollen industry. As an oil for paint it claims value as a 26-hour drier as against linseed 34 hours.

SEED

Apart from its use for oil extraction, sunflower 'seed' is a valuable poultry food, particularly for laying birds in winter. As well as the high oil content, unlike most other oil seeds, it has also a very high protein content. This combination makes it almost entirely balanced as a poultry feed. It is also in great demand for certain cage birds.

As a feed for laying poultry it can be fed at the rate of 1½ to 2 oz. per head per day. The oil content varies slightly with the variety and growing conditions but the average albuminoid ratio is between 1 :4 and 1 :6. It is therefore, on account of its high protein content, 17–20 per cent, not only not fattening as is maize, but is an almost balanced ration. It is especially suitable for poultry during the moulting season as the oil helps feather production

Research on sunflower protein in sunflower meal, carried out at the

[1] *Oils, Fats and Fatty Foods*, Bolton (London 1928).

University of California, shows sunflower protein to be a complete single source of amino acids for the growth of the young chick, when fed to provide 20 per cent of protein in the diet ((Proc. Soc. Exptl. Biol. Med. 60, 373–4, 1945). The fact that sunflower has for very many years been an ingredient of most cattle conditioning powders and poultry spices makes it almost unnecessary to stress its general conditioning effect. (See notes on growing sunflower, for the smallholder, in Chapter IV, analyses, Chapter XII, and Appendix I (4).)

Further, in the U.S.A., sunflower kernels are now sold, packeted, for human consumption as in the case of peanuts. (For dehusking see end of Chapter IX.)

SUNFLOWER FOR HONEY

Both Rhodesian and Russian reports state that no plant produces a finer honey and wax. It is, however, noticeable that certain varieties of sunflower are little visited by hive bees though sought after by the bumble bee. This is probably due to the greater depth of the corolla tube to the secretion of honey at the base of the style, where some strains of hive bees cannot reach it. This may be an important point for consideration when apiarists wish to choose a variety of sunflower to grow for the use of their bees.

BY-PRODUCTS

The chief by-products of sunflower come from the stalk and heads, after threshing, or the residue of the kernel after oil pressing.

Where large quantities of sunflower are grown it has been customary to use the stalks for fuel. This was particularly so in Russia where much of the heating in the peasant villages was obtained from this source. This was not economical in regard to the soil, as will be shown in Chapter X. At one time, too, much of the field residue was utilized by the Russian glass industry, on account of its high potash content. It seems, however, possible that sunflower could be a valuable source of cellulose, which forms so large a proportion of the make-up of the stalks.

The dried heads after de-seeding are a valuable source of feeding-stuffs for cattle, poultry, etc. This processing, making the dried head into feeding meal, has been carried out for some time in Rhodesia and a plant for the same purpose was erected in one area in Britain in 1944. Although the fibre content of the heads is rather high this is offset economically by the protein and oil content (see Chapter XII).

In Canada, apart from their use as poultry and cattle litter, the decorticated seed husks, finely ground, are, on account of their protein content, utilized as fillers in feeding cakes and meals. Additionally with the necessary bonding they are reported to be an excellent road surfacer.

SUNFLOWER CAKE

Feeding cake is the residue after the expression of the oil. Where the seed has not previously been decorticated, as often happens where somewhat primitive pressing methods are used, it will of course contain the husk and such is not only very disagreeable to handle but contains a high proportion of indigestible fibre. Such cakes were common from Russia and elsewhere. Where, however, cake is prepared commercially for an exacting market the husk is removed before crushing takes place and none is therefore found in the residue. Sunflower cake of the latter nature has a feeding value equal to the highest grade cakes—approximating to that from palm nut, groundnut and coconut. Its protein value is, from well milled seed, almost equal to that of linseed meal and is higher in fat. The feeding value will of course vary with the amount of oil extracted and whether the oil extraction has been only by heat and pressure or by chemicals.

Colonel Pollitt recently stressed the fact[1] that 'the most important stock feeds are oil cakes which are the residue of the oil-seed crushing industry'.

COMPOST

As the phosphates and potash in sunflower stalks and heads are high —the seed, as will be explained in Chapter III, being almost devoid of minerals except for the husk—it is obvious that if these residues can be returned to the land they will save considerable amounts of artificials for future crops, since almost all the plant has removed is thereby restored. While it is often simplest to restore the minerals by burning the stalk and spreading the ash, this should not be resorted to if the land is already deficient in humus. In the latter case the stalk can be disk-ploughed down in autumn but, failing a suitable implement or in view of possible mild winters, it is probably far more beneficial to compost.

Where the sunflower stalk is returned to the soil, as ash, compost or by direct disking, it is not an exhausting crop. This is shown where wheat has been grown after sunflower in this country, in comparison with wheat

[1] *Britain Can Feed Herself*, George P. Pollitt (Macmillan & Co., 1942).

on an adjoining plot grown after potatoes or roots. The South Rhodesian Agricultural Station at Salisbury, in trials covering four years, actually shows an increase in maize yield after sunflower, under the above conditions.

CELLULOSE

Attempts have frequently been made to utilize the stalk of sunflower for paper but the paper so made is of very inferior quality and this has been laid down to the high percentage of pith which it was impossible to separate from the fibre. This pith is of course mainly cellulose. In 1944 it was reported that a factory had been erected in Hungary for the extraction of cellulose from sunflower and maize stalks, after lengthy experiment by Government laboratories (*Chemical Age*, London, 22nd July 1944). This forms not only an entirely new industry but opens up considerable prospects as, if cellulose can be produced here, a gap will be filled in industry, while the value of the crop will be greatly increased. The extraction of cellulose will doubtless give a residue from which better quality paper can be produced.[1]

SILAGE (see also end Chapter V)

There is nothing new in sunflower for silage, it having long been so grown in U.S.A., Rhodesia, Canada, etc. In view of the high protein and oil content of sunflower such a crop is of great interest to the dairy farmer, particularly in view of the 1945 'More Milk, Less Wheat Policy', which overnight became, in 1946, 'Less Milk, Less Feeding Stuffs'!

In America and some other countries sunflower is grown as a forage crop, usually, however, made into silage rather than fed green. Such silage, prepared from the crop before the flowers have faded, has a value equal to clover hay (see Chapter XI), and 90 per cent better than high quality maize silage for milk production, according to Michigan research reports. Green fodder yields run as high as twenty or more tons per acre. Horses, rabbits, goats appreciate sunflower leaves.

Sunflower can be either silaged alone or as a mixture. When grown for silage as a single ingredient it is either cut when the flowers are just appearing or at a later stage. For comparisons of these two silages see analyses, Chapter XII. The best silage was made when the crop was cut just as the petals began to wilt. Neither molasses nor salt are used.

[1] See Appendix I (3).

SILAGE MIXTURES

A silage recommended in the U.S.A. consists of the produce of one acre of sunflower (heads only) with four acres of maize, to which is sometimes added one acre of beans.

Mixed silages with sunflower are made with maize, beans, peas, etc. These mixed silages are much used in Rhodesia and the U.S.A.

Rhodesian trials with Sunflower+Velvet bean silage over a number of years, in Southern Rhodesia, have been carried out on the following systems for which results are given (Salisbury trials):

(1) Sunflowers and beans sown in the same rows on the same day, spaced 9 x 36 inches.
(2) As No. 1 but beans sown 14 days later than the sunflower.
(3) Sunflowers and beans sown in alternate rows on the same day, spaced 12 x 20 inches.

Green Fodder Yields per acre:

Planting method	*Average over three seasons* Tons	*Average over four seasons* Tons
No. 1	10·2	11·0
No. 2	9·3	10·7
No. 3	10·2	11·1

This mixed silage was found more palatable than with sunflower alone. The inter-row spacing seems unnecessarily wide, especially for No. 1. Horse hoeing should be possible at 18 inches and would give more plants per acre and a higher yield.

The following trials were made at Bulawayo:

	Tons	Average
Sunflower+beans, same row, 18 x 36 inches	7·9	6 years
Sunflower+beans, alternate rows, 18 x 20 in.	7·8	2 years
Sunflower alone, 12 x 30 inches	11·0	4 years
Maize+beans, same row, 18 x 36 inches	6·0	4 years
Maize alone	6·2	4 years

Note. Sunflower gives a consistently higher yield to the mixture. The above yields are on the low side as the soil in question was shallow and the conditions far drier than obtain in Britain. The same remarks *re* spacing apply here, as for the Salisbury Trials above.

CHAPTER III

THE HISTORY AND NATURE OF SUNFLOWER

'The tall mass of a sunflower plant, with its heavy load of new seeds, has been built up in a short season from carbon dioxide of the air, with water and a small quantity of salts from the soil. Its chemical structure is highly complex, including not only the fibrous constituents such as cellulose, but also oils and aromatic substances.'—Statements at the Conference on Science and World Order arranged by the Division for the Social and International Relations of Science of the British Association for the Advancement of Science, London, September 1941.

The commercial sunflower of to-day is believed to have originated in Peru or Mexico, whence it was first introduced into Europe by the Spaniards in the sixteenth century. After its introduction to Spain, it spread to Bavaria in 1625, to France in 1787, and then to Hungary, Russia and other parts of Europe. Sunflower was reintroduced into the Argentine, as a commercial crop, in 1870.

The Anglo-Saxon term was 'Solsaece', the Spaniards calling them 'Girasol' and the French 'Tournesol'. All these terms imply 'turning with the sun' and seem to have been due to a rather imaginary belief that the flower turned with the sun. This is probably the same flower and the same legend of which Ovid speaks as 'turning to the sun'. Actually, however, the word sunflower is much more likely to originate from the resemblance of the flower to the rays of the sun.

The sunflower is distinguished by its cylindrical, strong, hairy stalks, growing from two to fifteen feet in height; its toothed leaves, covered with fine hairs, growing alternately from the stalk. The plant throws a strong tap root with many fine, fibrous side rootlets, near the surface of the soil.

The sunflower (Helianthus annuus) belongs to the largest natural order of flowering plants, the Compositae, which are characterized by the crowding together of individual flowers into heads. The heads of the compositae are surrounded by an involucre or rosette of green bracts, which protect the unopened buds and perform the usual function of a calyx. The flowers open in centripetal succession, from the outer ring inwards (this showing why the central portion of the head is also the last to shed its florets, an important indication of seed ripeness, as will be

shown later). In the sunflower the outer, or ray-florets, are larger and more conspicuous than the inner, owing to an enormous extension of the petals on the outer side of the floret. These ray florets are pistillate, having a pistil but no stamens, while the central or disc florets are hermaphrodite. The inferior ovary contains one ovule (attached to the base of the chamber) which ripens to form a dry one-seeded fruit,[1] the seed being filled with the straight embryo.

The flower-heads of the sunflower are a perfect example of an adapta-

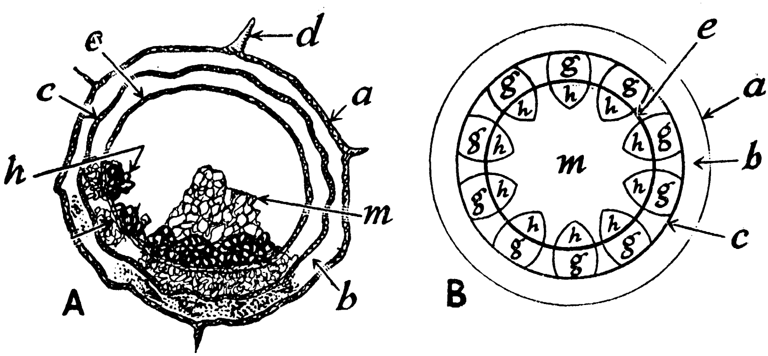


FIG. 4

Fig. *A* shows transverse section of sunflower stem: *a.* epidermis; *b.* cortex; *c.* endodermis; *d.* hair; *e.* cambium; *h.* wood; *m.* medulla or pith.

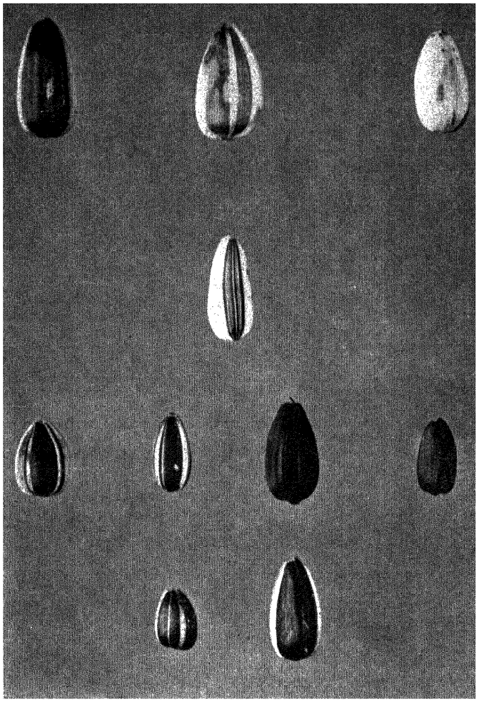
To avoid confusion, in Fig. *A* above, the internal build-up is only shown in part. Actually the whole cavity of the stem within the external epidermis ring is filled by a repetition or continuation of the structures, as shown in their respective position in relation to the axis. Fig. *B* is a diagrammatic illustration of a cross section of the stem showing the cambium ring completed and dividing the rings of bast and wood, the central portion being again filled with pith.

tion for insect pollination as the crowding of the flowers ensures conspicuousness and the pollination of a maximum number of flowers by a single insect visit. The honey, secreted at the base of the style, is protected by the corolla tube from visits of short-tongued insects (which may be why even bumble bees seem sometimes to visit sunflower more readily than hive bees, the former having a longer proboscis). When the flower opens the receptive surfaces of the two stigmas are pressed together and occupy a position at the base of the tube formed by the

[1] See botanical explanation, Chap. IX.

1 (*a*). A Russian scene in Britain. Starting a stook. Note lean of quadripod (leaves removed for clearness)

1 (*b*). A Russian 'giant' type. 7 ft. 6 in. high; diameter 15 in. Too slow growing. High percentage blind seed. Waste of ground space



2. Seeds of typical varieties
(actual average size)

No.	*Variety*	*Height*	*Grown*
1.	Manchurian	Giant	California
2.	Grey Striped	ditto	California; Russia
3.	Giant White	ditto	Russia; Rhodesia
4.	Saturn	Intermediate	Argentina; G.B.
5.	Pole Star	Semi-dwarf	Russia; G.B.
6.	Southern Cross	ditto	Russia; G.B.
7.	Mars	ditto	Russia; G.B.
8.	Jupiter	ditto	Russia; G.B.
9.	Sunrise	Dwarf	California; Canada
10.	Mennonite	ditto	Canada; U.S.A.

united anthers; the latter split on the inside and the liberated pollen fills the cavity of the tube and exposes it to contact with visiting insects: finally the style protrudes right through the anther tube and the stigmas spread apart and expose their formerly hidden receptive surfaces. Thus the life history of the flower falls into two stages, the first male and the second female. This favours cross pollination as compared with self-pollination. The sunflower is therefore practically self-sterile, though self-pollination may take place at a late stage, when cross-pollination has failed.

The varieties grown for oil seed are distinguishable largely by the shape, size and colour of the seeds, the height of growth and, in some cases by the colour of the flower, which varies from pale yellow to gold—the red modern varieties belonging to ornamental flower gardens.

The seeds are cylindrical, always more or less pointed at one end, varying in length from 10 to 15 mm., some being long, narrow and rather flat and other varieties more compact. In colouration the seeds vary from black to white with grey and striped as intermediates (see Illustrations),

We are, of course, only concerned with the hardy, annual sunflower (*Helianthus annuus*) for commercial oil seed purposes. The seeds of the perennial species are not commercially an important source of oil and only one perennial species, *Helianthus tuberosus*, the Jerusalem Artichoke, is of note for edible purposes and in this case it is not the seeds but the stem tubers that are made use of.

Of the annual species cultivated there are some fifty varieties chiefly distinguished either by their height or by the colour of their seed. The varieties naturally vary somewhat in their oil content and suitability for different conditions of soil and climate.

Sunflower is grown either as a fodder crop, fed green, ensiled or dried and mealed; or for its oil bearing seeds.

Both the seeds and foliage, apart from their oil content, are rich in proteins and it is this fact which makes sunflower seed a more balanced feeding stuff than maize or linseed. The protein value is approximate to that of peas—17–20 per cent, which, in addition to its oil, gives the seed twice the energy production of barley.

Primarily the sunflower types grown commercially divide themselves into the giant, semi-dwarf and dwarf kinds, according to their height. On the height of growth depends the length of time the crop will need to come to seed ripeness and so this factor mainly selects the type suitable for any special climate. In countries with long hot summers the giant or any other type can be grown but in temperate and northern climates one has to rely on the semi-dwarf types, if one is to sow in spring and be sure

PART II

CHAPTER IV

SUNFLOWER IN BRITAIN

'Agriculture can have a great future, but it will only succeed if it can prove to the nation that it is efficient.'—MINISTER OF AGRICULTURE, 19th February 1944.

EXPERIMENTAL WORK

Serious experimental work appears to have been commenced in 1941 by Prof. G. E. Blackman of the Imperial College of Science and Technology. It was in 1941 that a grant was first made for this purpose by the Ministry of Agriculture and, from 1943 onwards, similar grants were made by the Agricultural Research Council[1] to widen the scope of experiment and research on this crop. This of course followed the realization of the wartime shortage of edible oils in the first case and later of the world shortage that could be envisaged after the war.

The former lack of interest seems curious seeing that Sunflower had been well established as a basic crop in so many countries over such a long period of time. Still more so in view of the fact that it must have been patent that Sunflower found no drawbacks to our climate or soils, as was shown in almost every garden in Britain, and that the only other oil seed crop that we could grow, linseed, did not produce an edible oil. Only tradition therefore can account for this.

It was rapidly foreseen that the slow growing giant varieties of Sunflower, requiring some twenty-eight weeks from sowing to harvest, under favourable conditions, were useless for spring sowing in this country. The difficulty was of course that ripeness of the seed was not attained until the damp weather had set in and dampness not only hinders ripening but also brings with it Botrytis—mould on the heads.

In all some twenty varieties have been tested out, and of these all the semi-dwarf varieties are suitable for the length of our summer and climate, as their period of growth is only from 16–20 weeks. But many have been discarded for various reasons. Some five varieties were first selected both for their oil content and ease of cultivation and harvesting. Mars, a black-seeded variety; Southern Cross, grey-seeded; and Pole

[1] The Agricultural Research Council is a body independent of the Ministry of Agriculture and receives grants direct from the Treasury.

Star, slightly more striped and about a fortnight earlier than the other two, were all grown on a field scale in many districts in 1942–5.

But apart from selecting suitable varieties much has had to be done to determine the best time of sowing, soil treatment, soils to avoid, the best methods of harvesting, the technique of drying the seed, where field or natural drying was impossible, and, above all, the optimum spacing.

On trial plots it was found that yields of 30 cwt. per acre were reasonable and nearly 40 cwt. was achieved in one case. When these yields were compared with those published from many countries abroad it was found that the latter averaged from 7 to 15 cwt. only. From the outset we had been planting from 18 to 24 inches between the rows and from 12 to 18 inches between the plants. It was at once evident that spacing was of importance. Information received from Canada, U.S.A. and the Argentine showed that their normal spacings were from 18 to 36 x 24 to 36 inches. Obviously this wider spacing meant fewer plants per acre with consequent lower yield. Of course, in most cases, these countries were growing the giant varieties, throwing ripe heads up to twenty inches in diameter against the 10—12 inch heads from our semi-dwarf varieties here. This seemed to indicate that there was still a wide discrepancy in yield even when heads of double the diameter were obtained with half the number of plants.

Working on these lines a series of spacing trials were carried out. The results of these show that the optimum spacing is 9—12 inches between the plants, according to variety, and 15 inches between the rows. This spacing gives smaller heads but these heads are closer packed, carry far less blind or small-kernel seed while, of course, we are getting far more plants per acre.

In the early stages of experimentation, partly for unavoidable reasons, sowings were made late in April or early May. This meant harvesting from about the first week in September onwards according to variety and conditions. Generally speaking, provided the germination takes place immediately, which it will do, given sufficient moisture in the surface soil, the actual time of ripening is constant for each variety within a few days. But late September harvesting was not satisfactory as the weather cannot then be depended on and the incidence of Botrytis is always likely. The answer to this was artificial drying. From 1944 much earlier sowings were made, following a few trials in 1943, and, on trial plots, sowings have been made even in January and February, for frost-resistance tests. Early March sowings are definitely advisable as not only does this mean that ripening takes place at the most favourable time of year but the germination is quick and the consequent dangers

of wireworm and dry weather are almost always avoided. (See also notes under 'Sowing', Chapters VI and VII.)

FARM *versus* SMALLHOLDER

Something should be said here in regard to crop areas. Sunflower grows equally well in any sized plot but there is always a liability to sporadic bird attack, chiefly by the greenfinch, as the seeds ripen. This is more or less negligible on a plot of two acres or more, besides which, on these larger plots, where necessary, a rope 'gun' can be economically employed.

On the other hand sunflower seed is so valuable a feed for poultry that it is obviously an advantageous crop for the smallholder, poultry farmer or even backyarder. Here bird attack can be very serious, particularly if the plot is near a built-up area, as finches are particularly fond of this seed. In such cases therefore the grower must be prepared to take steps to keep the birds off the plants in the later stage. Greenfinch 'hunt' usually in flocks and a flock can clear 50 to 100 plants in a few days. The attack is sporadic and of adjoining crops only one may be attacked.

CROP EXTENSION

In 1942 only a very few farm crops were grown, probably a total of ten acres, in lots of two acres upwards. Otherwise only experimental plots were carried on. In 1943, however, the Ministry imported fresh supplies of the seed of the main varieties selected and this was distributed through various channels. The main crops were grown in Hants, Wilts, Essex, Herts, Beds, Bucks and Northants, and a total of probably fifty acres was grown on a farm scale, apart from a quantity grown by small poultry keepers.

The results obtained in 1943, though showing considerable variation in result, were most encouraging. The poorer results were due largely to certain soils, which showed themselves unsuitable, or, in some cases, to far too late sowing which, due to lack of proper threshing tackle at the requisite time, had to be harvested before fully ripe. There was, too, some undoubted loss due to growers not realizing the difference in the requirements of a crop of this nature as against our normal cereal and other crops.

As has been said, many of these crops were sown late—some from late April to the third week in May. The impossibility of field drying these late crops did, however, give a splendid opportunity of testing out artificial drying technique from which much was learned for the future.

The much larger acreage in 1943, scattered as it was over a wide area, allowed much to be learned as to the suitability of different types of drills and, more particularly, of the best machines for threshing. (See Chapters VI and VIII.)

Most of the 1943 crop, apart from that which was ruined for the purpose during drying experiments, was saved for seed for 1944. It had been realized that no bulk imports of fresh seed would be available. In 1944 some 250 acres were laid out on a farm scale in plots of 2–30 acres and over a wider area, including this time Leicestershire and even the Lake District, Lancs and Yorks. The month of April in particular in 1944 was exceptionally dry. Added to this wireworm was particularly prevalent and there were some unexpected attacks by fresh forms of animal and bird life. All this taught us still more and there is no doubt that the results of 1944 will be invaluable for the future. Generally those who have grown two years in succession, having learned something of the particular nature of this crop, have improved on their performance and there seems no reason to the writer why, if the correct lines are followed, a minimum average yield of one ton per acre should not become a standard in this country.

Following the results of 1943 certain basic necessities were decided on, drawn from data collected. In the first place it was found that harvesting, if the highest rate of extraction and the least possible decortication or splitting of the seed was to be attained, under conditions maintaining in Britain, could only be done by one particular type of thresher. This type of machine, while suitable for threshing certain types of seeds, largely market-garden crops such as leeks, is not suitable for normal farm crops of the cereal kind. It is therefore hardly an economic proposition for a farmer to purchase one of these machines for sunflower only, though it is an ideal machine for threshing maize. Sunflower can, of course, be hand threshed by several methods, including the flail, but such is again not practicable when it comes to dealing with acres rather than rods.

Furthermore it was found that, due to the uncertainty of our climate —the sunflower must be harvested quickly should bird or Botrytis attack develop, neglecting weather conditions—it was essential to have suitable drying plant available at short notice. Moist sunflower seed, with over 13–15 per cent moisture, will heat within twelve to twenty-four hours. Certain types of dryers used for cereals are totally unsuitable for sunflower, on account of the oily resins or waxes coating the seed, and the special types of dryers available are more costly than the 'tray' types.

CENTRALIZATION

With these findings suggestions were put forward to the Ministry of Agriculture, both by Prof. G. E. Blackman[1] and the writer, that farmers should be advised not to grow sunflower, owing to the risk of spoiling the crop, unless a suitable thresher and an emergency dryer of the right type were available. It was suggested that it would be better to form sunflower growing areas, to be extended from year to year, within which was a central plant for dealing with the seed, either with threshers that could be hired out or maintained on the drying plant to which the crops could be taken. The first of these areas was established in Herts, and a drying plant to deal not only with the seed but also by-products, was set up by Sunflower Seeds Ltd. at Chipperfield. This plant covered most of west Herts, Bucks, and south Beds. A second area, with drying plants, was also established in 1944 by Sunflower Development Ltd. of Leicester. This of course is planning on similar lines to that for the flax and sugar beet industries.[2]

POLICY

The Government, so far as the Ministry of Agriculture (Seed and Development Boards) is concerned, seem to have taken the long view and regard sunflower as an essential food crop for the post-war years. The first object has been to raise sufficient seed for resowing each year, until a large acreage is grown annually over as wide an area as possible, with the object of oil crushing, poultry feeding and the manufacture of by-product feeding stuffs.

CROP FUTURES

From the farmer's point of view this crop should appeal. Given proper attention it is an easy crop to grow, particularly free from disease and pest. But it does require a special technique. In pre-war years the price of sunflower seed was always above that of wheat. Furthermore if we are self-supporting to a large extent on our edible oils for margarine, etc., there will be a proportionate amount of home-produced feeding cake and meals for stock feeding, so that there should be a rising cycle of agricultural prosperity. All this home production, too, will ease the shipping problem for other purposes and at the same time ease the difficulties of import and export trade.

[1] See *Agriculture*, February 1944, Vol. I, No. 11, pp. 517–21.

[2] See Appendix IV.

Even with really vast expansion of sunflower crops there is no need to anticipate saturation of the market for oil for home consumption. Enormous quantities can be used for margarines of all kinds, for which sunflower is most suitable. Frying oil will absorb large amounts, especially when it is realized that a city of the size of Leicester consumes some ten tons of oil per month for this latter purpose. The encouragement of a home canning industry by the Government could also absorb large quantities where oil for canning is required. Sunflower oil will also be required for salads, many commercial and medicinal purposes and can take the place of olive oil for the more important purposes, where the finest oils are needed.[1] Sunflower will fit into any rotation and an addition to our rotations is always welcome, especially in view of certain plant pests and diseases which render succession of certain crops in a rotation not only undesirable but dangerous.

[1] For our pre-war imports of oil and oil seed products reference should be made to Chapter I.

CHAPTER V

CHOICE OF SEED, SITE AND PRE-CULTIVATION

'Look on ground as Mother Earth, never as mud.'—MARY HAMPDEN.

SUITABLE VARIETIES

As has already been pointed out, to meet the needs of our climate we have to turn to the semi-dwarf and dwarf species of sunflower, which have the shortest period of growth. Very many varieties have been tried out and many have been discarded. From the first, three varieties, Southern Cross, Pole Star, and Mars were found suitable both in respect of the above factor, and for seed yield and oil content. All these three have been grown on a large acreage scale in many districts. These were all imported seed. Other varieties too have been imported and added to the list of 'suitables' and though none had, up to 1945, been grown very extensively, it seems that some may prove even better, from one or other points of view, than the three already mentioned.

In speaking of varieties of imported seed we must not think of them as fixed, and those crops grown from such seed in Britain have only usually been true in certain characteristics of height or seed colour. Generally speaking, imported seed from commercially grown foreign crops is not remarkable for its purity of strain and therefore cannot be relied on to breed true *per se*. But, additionally to this, there seems little doubt that sunflower naturally tends towards black seed and that, while the white seeded varieties are albinos, the grey and striped seeded ones are crosses which are often very far from fixed. This lack of fixity or breeding true to type is amply exemplified in any crop. Striped seed tends to throw black and even white seeded plants and, what is worse, some of these plants show different periods of growth. Satisfactory harvesting, especially if such is to be done mechanically, cannot be attained if the major portion of the crop does not ripen evenly. It is therefore essential that, wherever possible, seed of pure strain that will breed true, at least in so far as even ripening as between plants is concerned, should be produced and demanded. This is a job for the breeder.

A crop that is uneven in maturing will cause difficulties in drying if harvested as a whole. If one attempts to get such a crop reasonably dry while standing a large portion will be very dry and therefore robbed by

birds. In the case where one has to cut the ripest plants one must either leave a portion of the crop to mature further or one loses weight of yield and also adds to drying difficulties, by amino-acids[1] left in the least mature seed.

While, in the case of a small percentage of plants showing different maturing characteristics, much can be done by severe roguing, a technique which also applies to those plants developing undesirable multiheadedness, this is obviously impracticable for the commercial grower when perhaps 25–35 per cent of the crop would need to be rogued for these causes. This can very easily happen, in growing from unrogued seed, for reasons given below.

The difficulty with sunflower is that each head may contain up to 2,000 seeds or so. Each of the flowers in the head, which will ultimately produce seed, is in itself self-sterile though the flowers of a single head are fertilized by one another by insect agency. But sunflower very easily cross fertilizes as between the flowers in different heads, by insects carrying the pollen from one head to another. Therefore one plant showing a different factor or factors of an undesirable nature, such as greater height, and therefore longer maturing growth, multiheadedness or seed of a type with a smaller kernel-husk percentage, may not only cross with all the flowers on a head of the desired type but with many such heads; and each of those heads contains a vast amount of seed. Any one of those undesirable factors may become a dominant in the second generation and the deterioration of a strain of seed is therefore very rapid. For this reason it is most undesirable to grow from seed from crops that have not been systematically rogued and it is highly desirable to sow each year only seed of the purest possible bred strain of the best varieties, obtained from a careful breeder. (See also Chapters III and XIII.)

The sunflower types suitable to Britain may be roughly classified by height of growth: (i) those of intermediate growth, up to seven feet, requiring early sowing and probably most suited to southern and dry districts; (ii) the larger class of semi-dwarfs from four and a half to five feet; (iii) the dwarfs, from two to three feet.

Varieties worth noting are the following—all, except the last, being from imported parent seed:

Southern Cross. Semi-dwarf, average five feet. Seed grey, showing slight stripe in varying degree. This variety has done well on most soils but tends to be very uneven in ripening and needs severe selection. Oil content good and husk percentage fairly low.

[1] Amino-acids—hydrolysed protein; intermediate products in the formation of protein from peptones.

Pole Star. Semi-dwarf, average five feet. The true type is about fourteen days earlier in ripening than Southern Cross, making this a more suitable variety for districts north of the Thames, and those with a shorter late summer dryness. Seed black with white stripe, much more pronounced than Southern Cross. Tends to throw back in seed colour and, unless rigorously rogued before flowers are open, will become largely multiheaded in the next generation. Good oil bearer and low husk percentage. Normally shorter in height and therefore better in exposed situations.

Mars. Black seed. Semi-dwarf, average five and a half feet. Rather later maturing than Southern Cross. This seems to breed very true to type and any tendency to multiheadedness has been shown to be removed by careful roguing. This is stated to produce a sweeter oil than most. Oil content good and husk percentage low.

Sunrise. Much grown in Canada. Originated at the Saratov Plant Breeding Station in Russia. Very dwarf—three to three and a half feet—with small, rather rounded, brownish-black seeds, showing some slight striping. Seems to have possibilities for combine harvesting on account of its height. As tried in this country Sunrise appears to throw many multiheaded plants which must be eliminated by selection. This variety is well worth more investigation and breeding.

Jupiter. A very small, black seeded variety. Intermediate in growth between Pole Star and Southern Cross, though at times of less height, and, on some land, should be earlier maturing than Pole Star. It comes very true to type and seems a particularly promising variety with a higher oil and protein yield than most. The heads tend to be more open than Mars but this tendency can probably be overcome by cultural and spacing attention or by selective breeding. Height averaging about four feet. Should again be particularly useful for either combine-harvesting or harvesting with a 'header'. The small seed will undoubtedly tend to a low husk percentage.

Saturn. An 'intermediate' type, growing from six to seven feet. Seed white with some black stripe and larger than the above varieties, while much more elongated. It needs early sowing—first week in March, in all but the drier districts with low rainfall in late summer. The larger seed renders it less liable to bird attack and it should prove a very heavy yielder, if properly attended to, on poorer soils. Saturn has a tendency to throw pure white seed and, occasionally, grey seed, both however true to seed type in shape.

There are two other promising varieties in their second season, as bred from second generation sports, showing proclivities to less blind seed in the head and very tight seed packing.

CHOICE OF SEED, SITE AND PRE-CULTIVATION

Although certain varieties tend to vary in oil production this again depends partly on soil and treatment.

Nothing need be said about the giant varieties beyond the fact that it seems possible that these might be sown as a very early spring crop, as most sunflower stands many degrees of frost, especially in the early stages. If this proves, after further experiment, to be the case then some of these may later be worth considering where they are shown to be heavier yielders or as having a higher oil content. On the other hand all the giants, as is natural for their large diameter, have very thick fleshy heads which take a lot of drying before threshing can take place and their height, too, makes them difficult to harvest.

As, in the main, we have to visualize sunflower as a crop for the production of oil, it is obvious that the first consideration in selection of variety must be towards that giving the highest oil content percentage and, from the crusher's point of view, a low husk to kernel ratio is of the utmost importance. It is found, as has been more thoroughly explained elsewhere, that it is the small seeded varieties which have the lowest husk ratio. For this reason Jupiter and, if certain undesirable qualities are bred out which reduce seed yield (e.g. a tendency to multi-headedness), Sunrise should be varieties worth while concentrating on.

British oil yield returns for crops grown in South and East England are much above the world average. On a dry matter basis the highest figure has been over 39 per cent and the average for mature crops 33 per cent.

CLIMATE

The only drawback in the English climate will be found in those districts which normally have heavy rainfall in August or early September which would make harvesting somewhat difficult and precarious.

CHOICE OF SITE

Some care should be taken in choosing the site for a sunflower crop, apart from soil. Sloping sites should be avoided where possible but if these must be used, provided they are not too steep, be sure to cultivate across the slope to retain the maximum moisture. This of course implies the advantage of contour cultivation where sites are uneven. It is also advisable to choose sites away from stackyards, high hedges and very large trees as well as away from built-up areas, as all these factors tend to provide conditions for bird attack in the later stages.

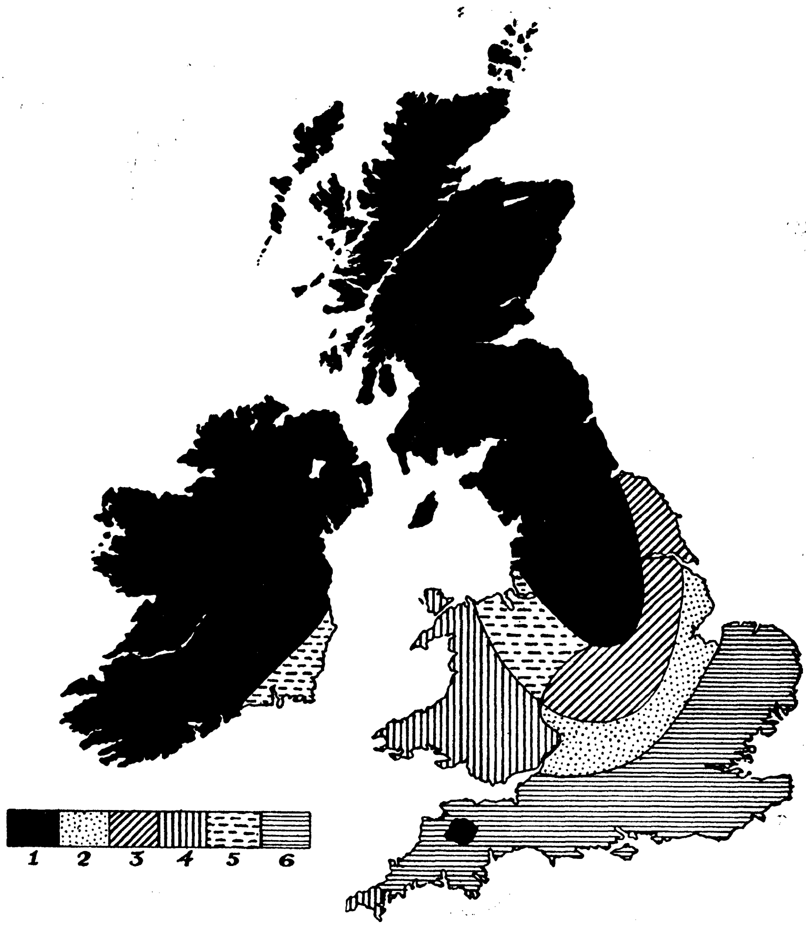


FIGURE 5

Map of the British Isles showing suitability of areas for sunflower, based on average August-September rainfall-*cum*-sunshine: (1) unsuitable; (2) suitable for most semi-dwarf varieties, mechanically harvested and, to the east, probably 'combined'; (3) suitable for early crops; (4) risky but possibly suitable for small crops, hand harvested; (5) probably suitable for very quick growing varieties; (6) normally suitable for all semi-dwarfs for combine harvesting. Rainfall conditions indicated above must of course be considered in conjunction with soil variations, which may well modify the general statements above. In the most favourable areas indicated soil patches occur which in themselves are far from ideal for Sunflower (refer to pages 63-6).

SOIL

Sunflower is not particular as to type of soil as is shown by the fact that in California it is grown on alkaline sand and has proved very successful on the sandy soil of Wisley and the Biggleswade districts of Bedfordshire. The soils sunflower does not like are very acid soils,[1] shallow soils on beds of chalk, badly drained clay or waterlogged land. On the other hand some choice must be made of soil. It is probable that sunflower grown for seed would be liable to throw too much stalk and leaf at the expense of seed, and with consequent delayed ripening, on very rich soils such as are found in the Fens, though this might be overcome by refraining from the use of dung, thus making conditions much akin to those of the black soils of the Ukraine.[2] Over-richness too makes for excessive height, late ripening and an inclination to lodging, under stormy weather in the late stages. The main requisite for successful germination, so essential for an even crop, that can be fully harvested at one time, is ample moisture and proper soil treatment. One must therefore choose land that holds moisture on the surface right into early April, no matter what the weather, and does not cake. This is largely a matter of soil technique and means that there must be humus on the surface, not too deep down, so that surface moisture is maintained or, at the worst, the subsoil moisture is not prevented from rising by capillary attraction by a deep ploughed-in mass of unrotted vegetable matter. Sunflower must have considerable moisture to germinate as the shell is a hard one. Failing this the seed will lie in the ground for many weeks without sign of life.

To what extent humus acts as a sponge to catch and retain surface moisture and rainfall is best observed in undisturbed woodlands. Even where woods or forests lie on steep hillsides, no rivulets form, even in thunderstorms, where the rain falls on the rotted vegetation surface. On all such soil vegetation itself flourishes in the driest season, as it does in the hedgerows and old orchards where no plough has ever passed.

'Decayed organic matter, by itself, or in combination with mineral soil, absorbs much more moisture than soil containing little or no organic

[1] Sunflower plots were included in the 'No Chalk' trials at the Hertfordshire Agricultural Institute, Oaklands, St. Albans in 1944. An immediate response was shown under chalk application, varying from two to four tons. Lack of chalk (or lime) in this case showed complete absence of plant.

[2] 'The most suitable soils are those which can be classed as of medium fertility—that is the light brash, and, in the drier districts of East Anglia, the lighter clays' (Prof. Blackman, *Agriculture*, April 1946).

matter; hence the greater the amount of leaf mould or other litter, the more rapidly will rain be absorbed. Rapidity of absorption is also influenced by the degree of looseness of the mineral soil. In the forest the mulch of leaves and litter keeps the mineral soil loose and in the best condition for rain absorption.' (United States Department of Agriculture *Year Book*, 1903, p. 284).

A similar statement is repeated in the same *Year Book* for 1938, pp. 609–10. Here is impressed the fact that the litter layer, once soaked, allows the excess water to trickle down into the mineral soil, whereas the sudden impact of heavy rain on bare soil tends to clog the tiny passages between the particles and, instead of the moisture percolating downwards, much of it flows across the surface, washing away soil and clay in its course and ultimately causing caking as the surface dries.

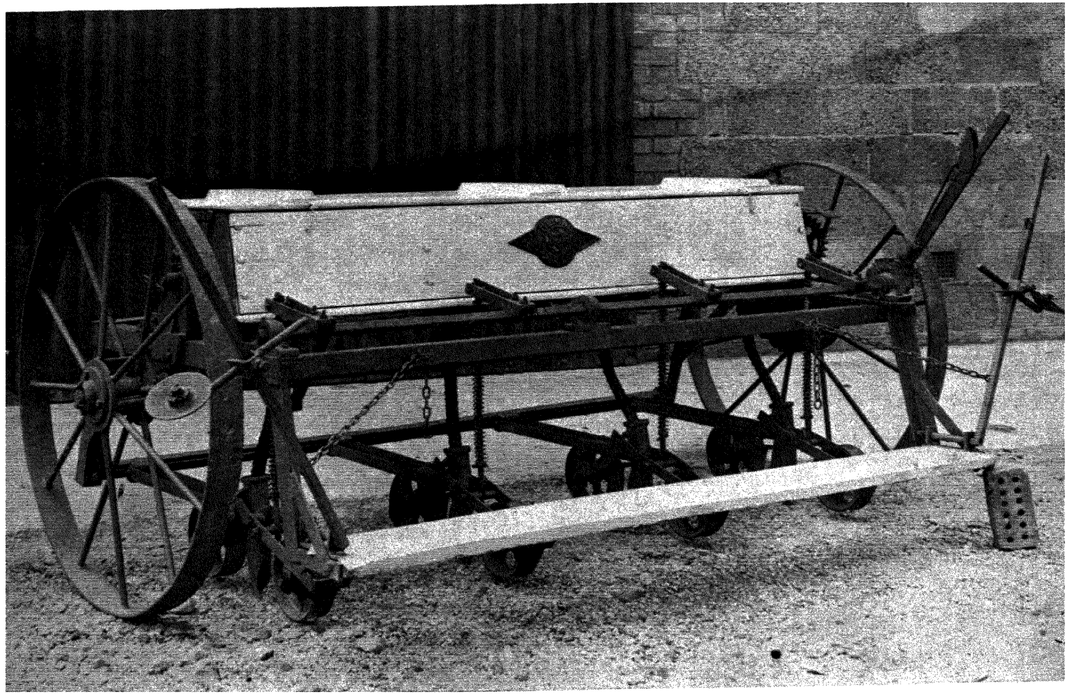
SOIL PREPARATION

For the reason stated above—easy germination—it is most important to pay particular attention to soil preparation and this preparation cannot be started too early in autumn.

Growers must understand that sunflower seed contains up to 35–45 per cent oil and this oil is not obtained from the soil or from any form of fertilizer. It is produced entirely from water and the carbon dioxide of the air, by the light energy absorbed by the green colouring matter, chlorophyll, so that soil feeding will only affect the plant and not the weight of seed kernel. A study of the analysis tables in Chapter XII will explain things better. What we are aiming at with a sunflower crop is the greatest amount of seed with the heaviest kernels and lowest husk ratio, i.e. the greatest quantity of oil and protein. It is highly probable that ultimately payment for seed crops will be made on oil content, the reasonable way from the oil crusher's point of view. It is therefore useless to waste money on fertilizers or to impoverish the soil to produce stalk, leaf and head and yet not increase the oil content.

Heavy sunflower crops have been obtained in Russia when there was only one day's rainfall from time of sowing to harvest. But sunflower does need ample moistuie and this it will draw through the root from the lower soil, once this tap root is established, even if the surface then receives little rainfall. For this reason the technique of soil preparation is important and it is worth while going into this question at some length.

Every piece of land has a certain water-table which is partly determined by the surrounding slope and drainage and also varies with the weather conditions, which may raise or lower it. If one digs into the



3. Dening 4-row root drill as used for sunflower

4. Interior arrangement of Dening root drill, showing the alternate cup feeds and boxes, adaptable for seeds of different sizes

ground some distance from a pond or river one eventually reaches water at the same depth as the surface of the pond or river water. One sees the same thing if one digs on the seashore where the water can actually be seen rising or falling with the level of the tide and each successive wave, since the sandy soil allows a rapid response to water level.

Tread on dry sand above the water level and the pressed down place becomes wet although one has not pressed it down as far as the water-table. This is due to the reduction in size of pore space and the capillary water in the soil becomes the gravitational water in excess of capillary water and can be removed by drainage. They need capillary water which adheres to the outside of the pore spaces formed in the structure of soil particle 'crumbs'—this by osmosis. What really happens is that, so long as particles of soil or sand touch, water will creep from one to another and surround its surface and so pass upwards to the soil surface. But if the particles do not touch the moisture cannot rise. All soil particles are rock and are therefore non-absorbent to moisture although, as has been said, they can hold and carry moisture on their surface.

There is no need for roots to reach the water-table. In fact except for certain plants and trees, such as willows, it is wrong that they should do so as they become waterlogged. They need moisture, not actual 'level' water and they can get this by capillary attraction, provided the soil particles are sufficiently consolidated to touch one another.

Deep ploughing, unless the soil is again consolidated, breaks this soil particle contact and the moisture only rises in part, among those particles that touch. The condition is even worse if vegetable matter is deep ploughed because cavities are made, almost like soil drains, some distance below the surface, which entirely prevent the rise of moisture. This is particularly the case with a crested furrow slice which leaves spaces under the slices; but is even worse with the rectangular slice unless the latter is well harrowed down, not so easy a matter. But with autumn ploughing and immediate harrowing, coupled with frost action, most of these subsoil spaces are filled in, especially if a wide broken furrow slice is made. Spring ploughing is too late for this very reason and is often the cause of complete failure in dry weather.

But there is a further difficulty when heavy loads of semi-rotted dung, straw or other unrotted vegetable matter are ploughed in. It is well known how much moisture straw or even hay will absorb on top of a cock or rick before the rain soaks far below the surface. This is because vegetable matter of this kind is very absorbent and not only holds moisture on its outside, as do soil particles, but takes it in to every cell structure within. If, therefore, this kind of matter lies under the soil

surface it forms a blotting pad which has to be completely soaked before any moisture can pass up from below. This lesson has been well learned by the farmers of America who have suffered so much from drought and consequent loss of crops and soil wastage. The humus and vegetable matter should therefore be incorporated by cultivators or heavy discs so as to lie near the surface where it will hold the moisture for the seed and the first tiny rootlets. Then there is nothing below to prevent the water from the water-table from creeping up as the surface soil dries out.

Comparisons could well be made between the germination of sunflower crops on lands shallow ploughed and well disked, especially newly ploughed turf, which does not break down readily, and those grown on deep ploughed land during dry spring weather.

The essentials for good disc preparation are as follows:

1. Make sure the discs are sharp and well lubricated.
2. It is best to use the front portion only for the first cut, to obtain depth, as, if the following portion is attached, it tends to prevent deep cutting. Weight well.
3. Make tests to set the discs to cut in, especially if the ground is stubbly or the manure not well rotted.
4. When using the front section alone always lap over half way on each 'road'.
5. Cross cut again at an angle.
6. Spiral disking is advantageous, giving the necessary extra turns to the outsides.

The rear portion of the cultivator is added once the ground has been well cut in, to break up the surface and leave as even a bed as possible.

Note. Official experiments by the United States Department of Agriculture, showed that, by the surface method of incorporation of organic matter, in place of ploughing, the yield of wheat could be increased as much as 50 per cent. See report in *Country Gentleman*, Vol. CIX, No. 11, p. 78 (1939).

Rising moisture undoubtedly tends to bring up minerals from a depth far below the surface.

Apart from the considerations pointed out above cultivation entails far less labour and is less subject to weather conditions.

Mr. Martin de Hosszu, farming at Tilsworth, Beds, well known for his work on experimental crops, has also demonstrated that land broken with the cultivator, produces finer crops than deep ploughing. (*Farmers' Weekly*, 28th July 1944.)

Disking in of organic material, especially dung, is best done in spring as winter rains tend to wash away much of its value.

This question of the importance of surface moisture supply is particularly stressed in a leaflet on sunflower production issued by the Agricultural Supplies Board of Ottawa (Leaflet No. 69). Here it is suggested that the tilth at time of sowing should for this reason be left 'reasonably lumpy', though of course it must be even to ensure an even stand.

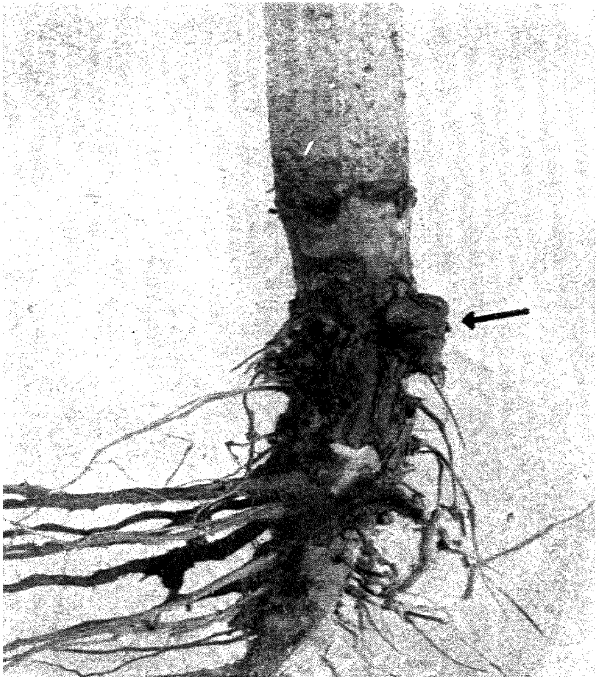
FERTILIZERS

Sunflower likes humus and this is best supplied by rotted dung or compost well incorporated in the surface soil in spring, say, twenty to twenty-five tons per acre. Rotting humus forms carbon dioxide gas which is heavier than air and sinks into the soil. There it forms carbonic acid, by being dissolved in the soil water, in the presence of which many chemical constituents of the soil particles that are only partially soluble in water pass readily into solution, the only form by which the plants can feed on the minerals—potash, phosphates, etc. Plants also live on humus as it is a rule of nature that growth in living plants takes place best on dead matter. Many lower forms of plant life, etc., such as fungi and bacteria, live directly on humus and the products of their activity have important bearings on the nutrition of the higher plants. No amount of inorganic artificials can supply deficiency in humus since humus provides the life. The minerals mainly build the plant structure, the bones or fibre, which support the living structures contained in the cells.

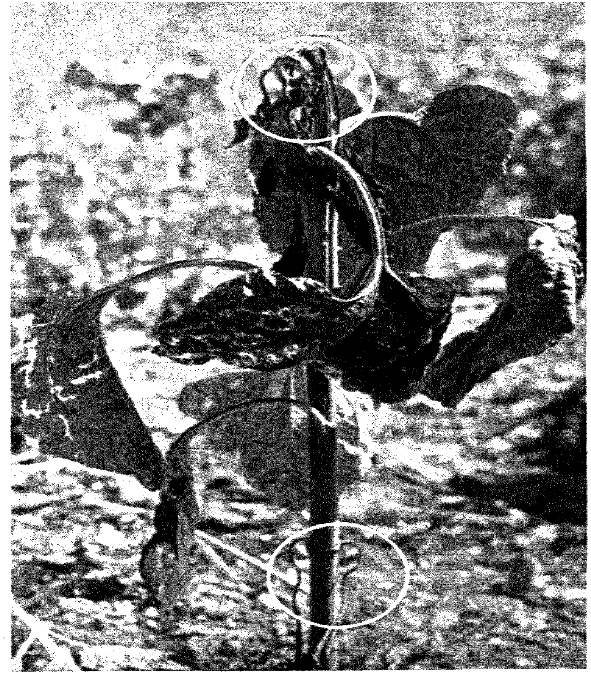
Constant tests made by the Agricultural Research Council have shown no appreciable increase in seed yield by the application of inorganic forms of phosphates, nitrogen or potash.[1] Naturally a soil definitely deficient in any of these, particularly lime which would otherwise leave an acid soil,[2] must be brought up to normal standard for the building of the plant body or we should get stunted, weakly stalks. But where fertilizers must be used, experience shows that they should be organic and not chemical, especially in the case of phosphates. Sulphate of ammonia is probably definitely detrimental for several reasons, largely because it tends to produce soft, sappy growth instead of strong wood, increases the thickness and moisture in the head, thus taking longer to dry at time of ripeness, and renders the plant more liable to

[1] A slight potash deficiency is even an advantage and encourages early opening, but excessive deficiency which would cause clover or barley to fail affects sunflower too.

[2] See note *re* Oaklands' Trials under 'Soil'.



5 (*a*). Stem of sunflower attacked by Sclerotinia sclerotiorum and bearing sclerotia, marked by arrow



5 (*b*). Sclerotinia (Esclerosis). Usually due to following a crop attacked in previous two years. Top completely collapsed. Below, leaves burnt up

6. Result of severe Aphis attack. Northants 1944

whereas plots on which farmyard manure has been used over a period of eighty years show no sign of deterioration. How far this is due to the action of the farmyard manure, with its organic matter, in maintaining the colloidal nature of the soil and how far due to the maintenance of the micro-population of the soil, a very important consideration in any case, has not been specifically determined but it seems evident that the artificials lack some essential factor or factors.

There is considerable evidence that wireworm attack is increased if not largely pre-caused by soil disturbed so as to prevent capillary rise of moisture or by a bed of matter ploughed in which has the same effect. It has long been known that consolidation of light soil lessens wireworm attack. The reason for this is that the plant makes less growth where moisture is deficient and is therefore more susceptible to attack, being more frequently soft as a result of delayed growth. This is especially the case with sunflower as is pointed out in Chapter VII. It is certain that, like all forms of life, wireworms need water as well as food and it therefore follows that where moisture is absent in the upper soil they will attack the plants for their juices, particularly if the latter are soft and delayed in growth. For this reason early sowing while the soil is moist is most advisable (as will be further set out in Chapter VII) as it not only quickens germination and growth but allows the plant to get away, with some wood in the root, before the wireworms get active. The wireworm population has long been known to be only relative to the severity of attack in comparison with the state of moisture and consolidation. Also undoubtedly semi-rotted vegetable matter is fed on by wireworm if there are particles which are still moist or alive.

OIL PRODUCTION IN SEED

It has already been stated that the production of oil by the sunflower is a chemical catalytic process from water and air though we do not know the method by which the plant achieves this. Without going into complicated chemical and scientific explanations, the reason why artificial manuring cannot increase the quantity of oil can perhaps be shown when the following facts are considered.

All vegetable oils are mixtures of the glycerides of certain fatty acids —in the case of sunflower oil, of the glycerides of oleic, linolic and palmitic acids. All these glycerides are formed by varying combinations of oxygen, hydrogen and carbon.

Water, whether obtained in the surface soil from direct rainfall or from the lower strata by capillary attraction, is composed of hydrogen

and oxygen and this is taken in by the plant root and passed through the hollow cells of the plant structure. The carbon is obtained from the atmosphere through the foliage, in the form of carbon dioxide gas.

The maximum oil-seed kernel yield can only be attained by supplying organic matter, whether by dung, compost or natural humus, in an easily available form, near the soil surface, for the plant and by maintaining free capillary action for the sub-surface water.

The kernel of the sunflower seed might be compared to a sponge of which the structure is a mass of fibre cells. This fibre only forms some 4–5 per cent of the kernel. Within these cells are accumulated the protein and oil. The proportions of oil to protein will vary with conditions, variety of seed and other factors. After the extraction of the oil the protein becomes the valuable part of feeding cake. But we need as high an oil content as possible. Protein is, of course, nitrogenous. It has not yet been shown how sunflower accumulates the nitrogen for the formation of protein. All organic matter is rich in nitrogen, particularly dung, so that the use of artificial nitrogen is not economical because, as we have shown, decaying vegetable matter is essential for successful sunflower cultivation in any case.

When the ripe seed is dried we have left an almost useless husk and a valuable kernel. The smaller the proportion of husk to kernel the better. But the larger the undried seed, i.e. the greater the husk proportion, the more water we shall have to dry away. Since neither oil nor protein is wasted in drying, it is obvious that the actual weight of our seed crop depends entirely on the size of our kernel and the amount of oil and protein it is capable of containing.

HUMUS AND PLANT HEALTH

Carbon dioxide is formed during the decay of humus. This acid helps to dissolve the minerals, whether contained in the soil particles, which in fact are all mineral, or whether added in the form of artificial manures, which should only be necessary where there is distinct lack of some particular mineral in the natural soil. It is sheer waste of labour and money to add potash if this exists in the soil particles. It may be that the potash is insoluble in the soil in the ordinary way but the addition of humus will provide the carbonic acid which will chemically dissolve it for the use of the plants. The action of carbonic acid on other minerals causes a chemical reaction by which the component parts are split up, forming soluble salts, available to the plant for the building of its structure, from the soil minerals.

There are other important reasons why humus, whether in the form of dung or decaying vegetable matter, is essential in the soil for healthy plant growth, whether of sunflower or any other crop. All decaying matter is a breeding place for the essential bacteria and minute fungi of the soil. The very fact that vegetable matter on and near the surface of the soil keeps the soil open, allows the entrance of oxygen, an essential for the aerobic bacteria and the micro-fungi. Both the bacteria and fungi help to break down the vegetable matter into its component parts on which the plant can feed. Here, of course, we are talking of the benevolent bacteria and fungi and not those which cause disease. There is constant competition between the benevolent and malevolent bacteria and micro-fungi and the prevalence of the benevolent species, as well as optimum plant growth under the best conditions, tend to make the plant more resistant to disease caused by the malevolent organisms. It has in fact been shown that certain micro-fungi produced in humus actually feed on and destroy certain forms of small animal life such as eelworm (see report in *Rhodesia Herald*, 4th September 1942, and similar reports by the Department of Agriculture of Ceylon).

The use of farmyard manure and compost increases the number of earthworms to the acre. The earthworms not only feed on the decaying matter but keep bringing the digested vegetable matter as well as subsoil to the surface. Darwin showed that earthworms on land in good heart could deposit as much as ten tons of wormcasts per acre. The experiments carried out by the Connecticut Experimental Station showed that wormcasts contain five times more nitrogen, seven times more *available* phosphates, eleven times more potash and 40 per cent more humus than is normally found in the top six inches of soil.

In a paper read to the Farmers' Club in 1939, Sir Bernard Greenwell stated (when speaking of earthworms): 'I am afraid few of us realize what a good friend this little fellow is to the farmer, and if we can only increase the population of the earthworm to the soil he will do a lot of our deep cultivation for us and aerate the soil gratis. Where we manured our grassland with artificials, we found the earthworms disappeared, but the following year a compost was applied, made from town rubbish mixed with dung, and immediately the wormcasts reappeared. . . . There is little doubt that he is a scavenger and if he disappears you will find his place taken by leather-jackets and other insects detrimental to the crops.'

When it is remembered that an acre may contain up to eight million worms and that they will penetrate to a depth of five or six feet into the subsoil it is obvious what part they play in soil aeration. Lack of aeration

prevents the formation of humus under turf, as is easily proved by the effect noted where turf is harrowed. What therefore is the effect when this aeration is extended to the much greater depth reached by the earthworm? And during this process the earthworm is helping to make humus from vegetable matter.

ARTIFICIALS REDUCE OIL CONTENT

There is an important biological aspect which makes the use of mineral, inorganic fertilizers useless and probably inimical to our aim of producing more oil. First it increases vegetative growth and fibre, and the longer the plant takes to build itself up the more delayed will be seed formation.

The seed of sunflower consists of two main parts, i.e. the husk or cortex and the kernel. It is the kernel that, like a sponge, contains the oil. The husk consists largely of fibre (over 50 per cent) and indigestible carbohydrates and the husk may form as much as 60 per cent of the seed.[1] We require as small a proportion of husk as possible. In other words the husk is part of the skeleton of the plant very akin to the shell of a crab, an external skeleton holding the kernel. The husk can be increased by artificial fertilizers but the husk is useless either for oil or feeding stuffs. Therefore it is waste to increase the size of the husk itself. The formation of the kernel we have already described and shown how little fertilizer affects it and how the latter cannot increase the essential oil content. But within the other cortex of the husk are numerous small cells containing air and water. Biologically it is found that the larger the size of the husk the greater the area of lining cells and their air and water content, as a result of which the kernel itself is actually smaller. In practice it has been found that the larger seeds actually contain the smallest kernel-oil proportion.

If therefore by artificial means we increase the size of the actual seed we are actually increasing the worthless husk and decreasing the oil we shall obtain from the kernel. Although by these means we apparently increase the bulk of seed it has been found that we decrease the weight of dried seed, the smaller resultant weight being due to loss of water from the larger cells of the dried husk and the smaller oil-kernel content.

It has seemed necessary to explain these facts in considerable detail since it has been found that many, not realizing the method of oil production by the sunflower plant and the biological structure of the seed,

[1] On account of the varying proportion of husk to kernel, crushers regard sunflower as the most difficult seed for oil extraction.

imagine that not only can the bulk and weight of fresh seed be increased by artificial fertilizers but that such an increase adds to the oil obtained. This comes from regarding sunflower seed on parallel lines to cereals.

MANURING

Report from *Rhodesia Agricultural Journal*: 'Well-rotted farmyard manure (or compost or green crop) is the best fertilizing agent for sunflowers, except on the very fertile soils or soils containing much humus. On such land and if heavily manured, the plant is liable to produce a number of lateral branches, which are undesirable, and the yield of seed is apt to be reduced owing to excessive vegetative growth.'

Report from the College of Agriculture, University of California, 1944, on Sunflower crops in that State, says that 'no fertilizer is ordinarily used'.

It is undoubtedly preferable to apply and disc in the dung in spring, some weeks before sowing. Dung applied in winter loses much of its goodness through water washing it into the subsoil. It seems strange to us that dung is so often stored in heaps on the fields without any attention to its protection. Exposure to the weather causes loss of nitrogen compounds in the first place and much of the other valuable constituents are washed through into the ground. When straw is a drug on the market, it would amply repay the owner to cover his dung heap with a foot or so of straw. This by its absorptive qualities would prevent rain from reaching the dung, while much of the former would rot through the winter months. The covering too would prevent loss of the generated heat, which causes the desired decomposition, and, in the case of cattle dung, fermentation naturally will go on for some eight months.

SEED BED

Further cultivation before sowing involves the making of an even seed bed, fairly fine and free from hardened clods, to facilitate even depth of sowing. Do not worry if bits of straw, etc., show somewhat untidily on the surface—Nature doesn't.

ROTATIONS

Sunflower can follow in any rotation. Care should, however, be taken to see that it does not follow a bean or other crop that has been attacked by sclerotinia. This latter fungus will attack sunflower and its hardened

black masses of mycelium (sclerotia) will lie in the soil for two years until another suitable host crop is grown. (See Chapter VII.)

GERMINATION

Sunflower normally has a very high germination, probably over 90 per cent, and like all oil seeds, holds its germination for a number of years, the writer having grown crops from seed eight years old. With this vitality, it is therefore understandable that germination is not easily destroyed so that frosts after sowing are not to be feared. In suitable moist soil germination is rapid, though naturally speeded up according to soil temperature. In trials sown at the beginning of January it has been found that, although the plants did not show above ground till the end of February, there having been no warmth, they had actually thrown a tap root some three to four inches long and these early plants were resistant to other factors, such as sixteen degrees of frost, later, as well as to rabbits which, when foraging in April, ate later sown plants grown adjacent, the latter being more succulent.

SILAGE CROP

Just as the treatment of sunflower for seed production differs entirely from that for other crops grown in Britain, so the treatment of sunflower for silage is diametrically different to that followed when the crop is intended for seed, since, of course, the greatest rapidity of growth, to avoid indigestible fibre, and the maximum vegetation are now desired.

Of the standard varieties in commerce in this country probably equally successful results will be obtained with Mars, Southern Cross, Pole Star or Saturn—the latter requiring longest growth period and being tallest—the very dwarf varieties being discarded as providing too little green matter.

The question of fertilizers must be left to the grower, depending on the state of the land and what fertilizer is available, bearing always in mind that rapid growth and vegetation are the main aims.

The rate of sowing should be from 10 to 15 lb. per acre, depending on the type of drill used.

The crop must be cut when the flowering stage is reached (crop about one-sixth to one-third in bloom) and NOT when the seeds have set. Then not only will maximum weight be obtained but the foliage will be most succulent, indigestible fibre content lowest and so the silage will be less

wasteful. Harvest by hand or with a binder. Before putting in silo the crop may be treated with a cutter blower but a better result can probably be obtained with a shredder such as that manufactured by Ransomes, ensuring much tighter packing and disintegration of the stalks. A completely airtight silo is essential to get best fermentation and complete breakdown. No molasses or salt are used. Average green yield will be from 20 tons up, as much as 24 tons having been obtained with the giant varieties, however, varying with land, treatment and time of sowing.

It is most essential that the silo used should be airtight in all respects, for which reason 'pre-fab' temporary silos are not desirable, since entry of air will cause the wrong type of fermentation and a sour and useless silage will result.

CHAPTER VI

SOWING AND CULTIVATION

'There can be no living science unless there is a widespread instinctive conviction in the existence of an order of things, and, in particular, of an order of nature.'—WHITEHEAD, *Science and the Modern World.*

TIME TO SOW

Early sowing—and there is a constant tendency to sow most outdoor crops far later than necessary—has two advantages in particular in regard to most plants, and more especially in the case of sunflower.

The process of the manufacture of carbohydrates from water and carbon dioxide from the air, so necessary in the formation of oil, can only take place, in the green plant, in the presence of light and in cells containing chlorophyll, the green colouring matter. On this ability too depends, of course, the life of the plant. This process of assimilation and manufacture is known as photosynthesis. The process ceases in the dark and is slowed down according to the degree of light.

De Saussure (1804) proved that sunflower, in absorbing carbon dioxide, increased its dryweight but it was left to Liebig (1840) to show that the sole source of this carbon was air and not humus, as had been previously believed.

The rate of photosynthesis is largely influenced by the following external factors:

(*a*) Light intensity.
(*b*) Temperature.
(*c*) Water supply.
(*d*) Carbon dioxide concentration.

Prof. F. F. Blackman showed, by his *Theory of Limiting Factors* (Ann. Bot., 1905, 19, 281), that 'when a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor'; so it will be seen how important the earliest possible sowing is. Early sowing means the greatest amount of growth during those weeks when the longest daylight, the strongest light and the maximum temperatures can be reasonably expected. If we take into consideration with this what has already been said, in a previous chapter, about the preparation of the soil to ensure maximum availability of surface and subsoil water (factor (*c*) above) we have pro-

7 (*a*). Stooking. Tying two plants about 6 in. below head

7 (*b*). Stooking. Completed quadripod showing tie

8 (*a*). A completed stook ready for piling

8 (*b*). A stooked crop. Kinsbourne Green 1943

gressed a long way towards affording to the plant the main essential external factors.

But early sowing in sunflower also influences seed production since the sunflower, being practically self-sterile, needs the assistance of insects to fertilize and produce fertile seed. Sunflower crops at best flower over a rather irregular period and in the case of the multiheaded varieties the side buds develop much later than the main head. Late sowing may well bring part of the crop into flower at a period when insect life is either comparatively reduced, or, by reason of cold, dull weather, inactive, so that fertilization is either absent or only partial. Late sowing may also delay germination due to early dry spells or the latter may check growth. Delayed germination will again entail late flowering with the above results. Checked growth is often a cause of non-inherent multiheadedness and this state not only reduces the size of the main head but produces those side buds, which, for reasons mentioned above, cannot be fertilized.

While with the early ripening varieties successful crops can be harvested from May sowings this can only be achieved under ideal conditions in certain of the drier parts of the country. To achieve success with such late sowings one must be assured of:

(*a*) Sufficient moisture for rapid germination.

(*b*) The certainty of hot weather at the ripening and harvest period.

The risks of these late sowings are great and should only be run in a case of necessity due to failure of an early sowing, etc.

Generally speaking the last week in March, or, in East Anglia, Kent, Sussex and Hants, the first week in April, is the latest ideal time. April, however, is not advisable where wireworm is present and, as the climate in Britain seems to be slowly changing and the traditional April showers are more likely to occur in March, it is better to regard the earlier date as the latest desirable. It would be preferable to sow most varieties the second or third week in March, for many reasons shown elsewhere, with Saturn the first week of that month. February sowing seems to cause much seed to rot in the ground if the weather should be cold and wet.

In the case of light or sandy soils the seed bed must be consolidated to obtain even germination. Consolidation of heavy soils is detrimental and may lead to entire failure due to caking and lack of aeration.

AMOUNT OF SEED AND DRILL TYPES, ETC.

Sunflower seed varies from 30 to 40 lb. to the bushel. The amount of seed required per acre depends on the method of sowing. With most multi-row drills it is advisable to allow 15 lb. to the acre. With single-row

root drills and those of the 'Planet Junior' type sowing can be done with 7–8 lb. per acre and with a few drills with even less. Hand sowing, after marking the ground with shallow drills, can be done with 4½ lb., or thereabouts, according to seed size and variety. Ten lb. per acre gives approximately one seed per 4 inches run with 18 inches inter-row spacing, though closer with the small seed varieties.

With the small seeded variety Sunrise satisfactory stands are obtained in Canada with a seeding rate of 4–5 lb. per acre. The inter-row spacing in the Dominion is, however, the uneconomically wide one of 36 inches, but 8 lb. are sufficient per acre with an inter-row spacing of 18 inches.

At present there is far too wide a variety of drills in the country to be didactic on the type to be used. Of the multi-row drills it can be said that a very even plant can be sown with that made by Messrs. Dening of Chard and also with the old 'Bedford' Drill, so largely used in the Bedfordshire market-garden districts. Many drills can undoubtedly be calibrated to sow sunflower. Even sowings have been made with an Oliver drill.[1]

Drills with a large box are a nuisance as 10 lb. of seed is lost in these and some steps must be taken to remedy this. One can either make the drill box into small compartments, covering over the outlets not required with paper, wood or card stuffing walls, or one can bulk the seed by the addition of a quantity of barley, old sugar beet seed or similar. If the latter germinates it can be cut out later.

Many drills must be discarded because they are incapable of being adjusted to the right spacing between the rows. Some drills have the feeds adjustable laterally and others, particularly those used for close crop work, can, of course, have alternate spouts blocked temporarily. In some drills it is impossible to sow within the limits of depth desired. It has been found that some types, particularly those of the forced feed type, due to the shape and size of sunflower seed, are apt to split the seeds, rendering them useless for germination, but slight cracking of the husk does not seem material.

With all drills whose suitability for sunflower is unknown, particularly in regard to spacing in the rows, it is advisable to make a trial in advance so that the necessary regulation or adaptation for rate of seeding can be carried out before actual work on the field has been begun. The simplest method is to run the drill once or twice over a stack sheet, after charging with some seed, until the right rate has been obtained.

Failing a suitable drill we have made good use of a bouting plough. The shoe was set to a depth of 1½ to 2 inches and in this level drill, with

[1] See Appendix II for various drill settings and quantities.

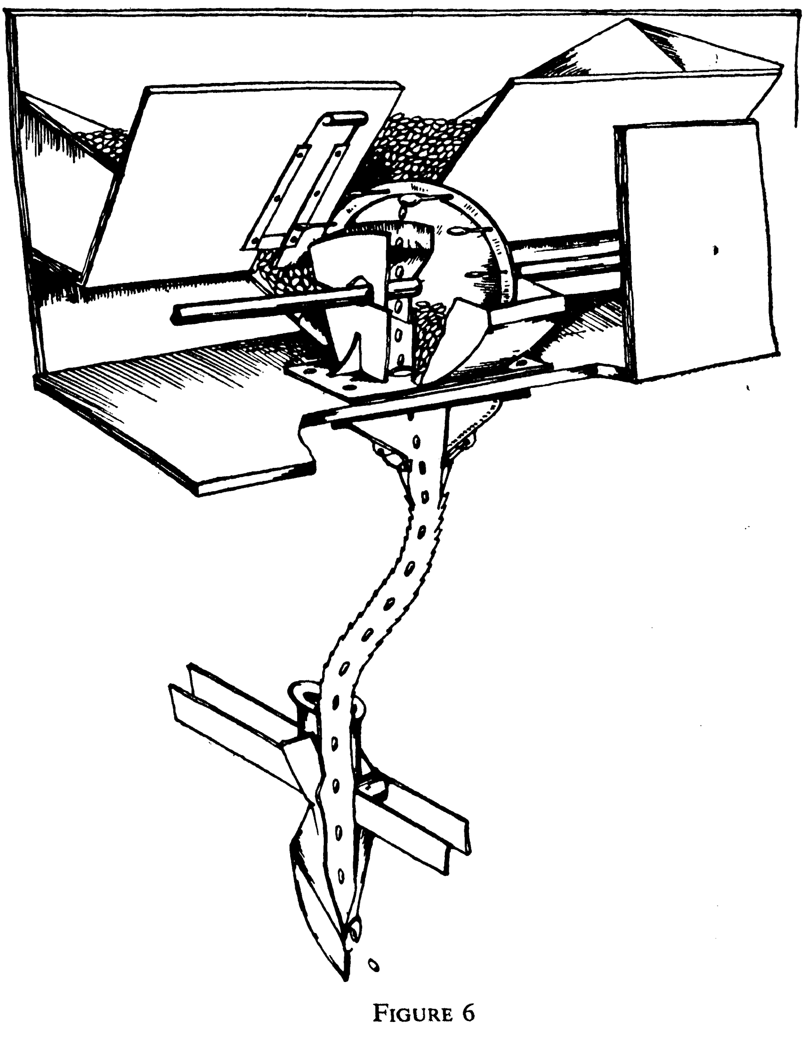


FIGURE 6

Dening Four-Row Root Drill showing seed feed arrangement.

firmed bed, the seed was sown by hand. Light harrowing covered in the seed. Seed must not be sown *on* the bouts or ridges.

On land not liable to cake the seed-bed may be advantageously rolled with a ring roller.

SPACING

Following many careful plot tests it has been found that the optimum spacing for highest yield with the semi-dwarf varieties of sunflower is 15 inches between the rows and 9–12 inches between the plants (10 inches Mars and 12 inches Southern Cross; 9–10 inches Pole Star).[1] In the case of the smallholder this inter-row spacing of 15 inches provides no difficulty when it comes to inter-row cultivation. Some growers on farms may consider it too narrow for horse or mechanical cultivation. It is, however, far from impossible to horse hoe in this spacing and a Row-Trac cultivator will also operate comfortably. But for those who wish to use other means it is possible to extend the inter-row space to 18 or even 20 inches. Greater spacing than this is not advisable. If, however, the inter-row space is increased from 15 to 18 or 20 inches the space between the plants must be reduced—say to 8, 9 and 10 inches according to the variety—so as to give approximately a similar number of plants per square yard. We aim at eight plants per square yard for Pole Star and six to seven for Mars and Southern Cross. Close spacing tends to medium sized heads producing smaller seed. The smaller seed has an appreciably higher oil content.

Where sunflower is hand sown the most important factor is to avoid uneven depth of sowing. For this reason dibbing is not to be advised. It is much better to mark the plot with a tractor marker in either direction, setting the marker to the required width and depth of sowing, and, where the marking lines cross, to drop the seeds. Provided that the seed is obtained with a good germination test, say 95 per cent, only one seed need be dropped per hole. Hand sowing is advantageous from two points of view: less seed is needed and there is no need to cut out surplus plants later. The latter factor not only balances out on labour but actually saves damage to other plants which are required to be left, as will be explained under 'thinning', below.

Tests carried out in Canada show that not only is seed yield increased by closer spacing in the rows but also oil content:

[1] The narrower spacing makes for ease of harvesting if this is to be done by 'combine'.

Spacing in rows	*Lb. per acre*	*Kernel percentage*	*Oil percentage (whole seed)*
6″	920·6	56·8	29·1
18″	877·7	55·0	26·4
36″	689·7	54·1	25·4

The above tests were carried out with Mennonite. Naturally the increased yield in lb. per acre can be put down largely to the number of plants per acre on narrower spacing though with the 6-inch spacing the average head diameter was reduced to 4 inches as against 6 inches in the wider spacings. But it is the oil percentage which is the outstanding factor. The rather low total seed yield above is accounted for by the fact that the tests were carried out with an inter-row spacing of 36 inches.

Correct depth of sowing is ½ inch to 1 inch on heavy soils to 1½ inches on light soils.

AFTER CULTIVATION

When the seedlings are beginning to show their first true leaves, inter-row light hoeing should be carried out. This can be done even earlier should the ground tend to cake.

Continual inter-row cultivation is not necessary, as far as weeds are concerned, after the plants are 12 to 18 inches high, as sunflower is a smother crop and will grow away from and tend to overcome its own weeds, especially on the spacing recommended above. In any case, should it be necessary to tackle weeds further or to break up the land between the rows at a later stage, any cultivation or hoeing should be only lightly on the surface. The fibrous roots extend rapidly some distance from the plant and lie near the surface. As these rootlets form the anchor for the plant, any injury to them will cause the plant to be a prey to strong winds, apart from reducing its food supply.

Weedy land should have been avoided, of course. The use of a flame thrower immediately after sowing would delay weed growth till sunflower was established.

Chemical weed control does not as yet appear feasible for sunflower as the plants will not stand up to spraying with sulphuric acid, copper chloride, DNOC compounds or the growth promoting substances.

THINNING

Thinning where necessary should be done before the plants are six inches high. A light hoe may be used but care is needed not to damage the

rootlets of adjoining plants or to loosen them in the soil. Sunflower over six inches high cannot be 'pushed out' as mangolds, since the tap root has too firm a hold. Nor should they be cut off above the surface as the remaining stalk then forms several shoots, finally growing to a bushy plant which takes up more space than had the original growth been left. So rough cutting simply means that the work must be done again.

By far the most successful method of thinning, and one which is less dangerous and actually takes the shortest time, is hand pulling. Straddling one row and using both hands, the rows on either side—three rows in all—can be hand pulled more quickly than hoeing out a single row.

Cross blocking mechanically with the hoe lines spaced to leave plants at correct spacings and set to a depth of 1 inch is probably cheapest and would prove the most efficient.

WIND DAMAGE

A healthy sunflower crop will stand much wind, especially crops of the lower growing, semi-dwarf varieties. It has been found that freak storms of considerable violence, especially those which form eddying gusts, will sometimes break and bend the plants, though in such cases it is usually only in the late stages of growth and the plants fall against one another without actually doing much damage to seed yield.

On the other hand, since sunflower is comparatively shallow in its fibrous root system, these lying near the surface, wind is liable to uproot the plants when grown on a light or medium soil, since the anchorage in such cases is insufficient. Under such soil conditions it is advisable—as indeed with many other crops—to mould up the plants in the rows, to a depth of three to four inches when about a foot high. This allows for additional fibrous root growth and a more secure anchorage.

SEED FOR REPRODUCTION

As sunflower tends to cross fertilize easily, where seed is grown for reproduction, it is not advisable to grow two varieties within, say, a mile of each other.

Selection of seed should be made only from those heads which show seeds well filled with kernel. As is explained elsewhere, these are not the largest seed but usually are found in very closely packed heads, the seed appearing rather of medium size, shapely and even in contour.

Roguing must take place and the following types of plants should be

discarded rigorously at the earliest possible moment: (1) those tending to throw side heads, which, ripening at different times, if left, reduce the total yield and, in any case, are more laborious to harvest; (2) plants that hold the face of the head horizontally. These will not bend their heads on ripening and are therefore very prone to bird attack; (3) all plants showing signs of disease; (4) heads showing hollow centres; (5) heads in which the seed is not close packed. Though types (4) and (5) are often caused by weather conditions these types also seem inherent in certain strains.

CHAPTER VII

PESTS AND DISEASES

WIREWORM

The fact that wireworm are particularly fond of sunflower at the early stage—the moment when the seed husk opens in particular —and the low rate of seeding per acre make it obvious that this is a pest to be avoided. In 1944, partly due to the almost universal dry spell in April, wireworm was exceedingly destructive of sunflower crops, plots of as much as eight acres being completely cleared before the plant appeared above the surface of the soil. On the other hand this very fact has allowed much data to be gathered and previous theories to be proved which have shown that wireworm destruction of this crop can probably be almost entirely avoided.

It is generally accepted now by investigators that the actual wireworm population per acre in the soil is only a rough index to the amount of damage they will do on a given crop. In fact, in the case of wheat, there are plenty of examples known where, though tests have shown up to 2,000,000 wireworm to an acre, the damage to the crop has been negligible, while other crops of the same variety of wheat, on land with a wireworm population of only 200,000 per acre, have been completely decimated.

The life history of the wireworm is not entirely known. The parent click beetle lays its eggs in cracks in the soil, and very dry weather is therefore favourable for this process. The egg laying takes place chiefly in grassland so that disturbance of the eggs by cultivation is avoided and, of course, there is ample nourishment in the grass roots when the young hatch out. The wireworm stage can continue for at least four to five years during which time the wireworm or larvae grow, but do not, of course, multiply. It does not therefore follow that they are more voracious in any particular year after the ploughing up of grass. Much to the surprise of many agriculturalists wireworm showed itself in some cases more destructive in 1944 on fourth-year plough than on second and third year, which was contrary to previous experience. The actual number of years that wireworm will live in the soil before reaching the chrysalis stage, preparatory to emerging once again as the beetle, has not yet been ascertained and it is possible that this is partly dependent on the food supply. It is, however, a fact that while fairly recently ploughed

9. Crop drying on fences

10. Cutting sunflower heads by hand

grassland seems to have most prevalence of wireworm they have been found in very large numbers and very destructive on land which has been under the plough for a very considerable period indeed. In hard weather, in winter, the wireworm will descend several feet into the soil.

The chemical destruction of wireworm is not a practicable proposition for the farmer. Chemical solutions exist which are fatal to wireworm and these are of use to the gardener and market gardener. But the fact that these solutions must be applied to the land at the rate of two gallons per square yard renders them, as we have said, not practical to the arable farmer. It therefore follows that we must find some way of preventing the existing wireworm from attacking the crop.

Wireworm, like any other form of life, needs both food and water. Where there is sufficient food it is probable that the wireworm obtains sufficient moisture from this. The fact that wireworm are more destructive in dry weather shows that the crops are then more susceptible as they cannot grow away from the attack. That wireworm will not attack certain plants in certain stages of growth can best be shown in the case of sunflower. And it is known that wireworm can live many months without food. In fact there appears to be a period, usually at its peak in April, when wireworm feed most voraciously after which there comes a further period when they cease to feed actively.

Recently the writer had under observation a newly ploughed piece of very old grassland. The land in question had been subject for a very long period of years to intermittent flooding both from a river and from a mill dam. Consequently the soil in question was almost alluvial and liable to become exceedingly friable to a great depth in very dry weather, since such soil does not naturally easily consolidate, due to the great amount of humus. Partly from necessity and partly for experiment, although it was obvious that this ground had a high wireworm population, it was decided to plant certain crops.

During March there had been plenty of rain and the ground was well saturated. It was therefore easily consolidated after ploughing and disking. Under these conditions two acres of sunflower were sown in the last week of March. The soil conditions were ideal for germination and the sunflower came away quickly, at a period before wireworm normally becomes really active. The whole of April was without rain but there was a fairly heavy fall during two days at the commencement of May. The nature of the soil did not prevent cultivation under these conditions though the very high humus content would naturally absorb considerable quantities of water but prevent it penetrating very deeply. At the end of the first week in May, two acres of maize were sown, after con-

solidation of the soil, on the plot adjoining the sunflower. It is here to be noted that the use of the roller was actually extended rather beyond the acreage required for the maize seeding—a point which is of importance in this particular history.

The near surface moisture was sufficient to allow a regular and quick germination of the maize, which, in spite of the following drought, grew favourably to a height of four to five inches above soil level, having been sown four inches deep to prevent rook damage, a depth which also aided germination before the soil again commenced to dry out.

But having reached the above height it was noted that the maize plants were wilting badly and inspection showed that plant after plant had been cut off slightly below the surface by wireworm. The whole crop disappeared in this fashion in about ten days.

Examination of the sunflower showed that wireworm were feeding at this stage on the fibrous roots of the sunflower but the latter was by now some twenty inches high and the attack was not affecting the crop. The rootlet attack was doing no real damage since the plant was capable of forming fresh fibre roots. No sign of attack was found on the tap root or the stem at ground level—obviously because this had now reached a very woody stage and had little moisture content.

It was therefore pretty obvious that the pests were lacking moisture, the ground now being very dry, and the succulent maize shoots had provided this while the fibrous young roots of the sunflower were at least the best substitute the wireworm could find. The same thing happened to an experimental crop of millet which was sown on another patch of the same field about May 20th. Most of this plant was taken either at the moment of germination or just after it had come up some two inches. The whole crop disappeared.

We now come to the plot adjoining the maize, a matter of about half an acre. It will be remembered that a strip of this land had been roller consolidated when the maize patch was prepared just after the early May rainfall. This strip and the rest of the half-acre was planted with marrows towards the end of May. Practically all the marrows were taken below soil surface on the unconsolidated patch while those on the patch that had previously been consolidated were hardly attacked at all.

It has long been known that consolidation has some effect on wireworm attack but here seems to be the reason as well as a useful lesson. The marrow patch where the wireworm were most destructive and which had not been consolidated was found to be very dry to a depth of several inches, in fact rather like a soft mattress, while the consolidated patch showed considerable moisture just under the surface, consolidation not

only retaining near-surface moisture but allowing subsoil moisture to rise. The plants on the latter made vigorous growth and were less susceptible to attack.

And how quickly wireworm will eat sunflower can be gathered from the fact that where a crop has been sown under dry conditions as many as five of the 'worms' can be found feeding on the young shoot as it emerges from the seed, some even entering the split seed itself.

On land deficient in humus, however, wireworm attacks have been entirely on a blitzkrieg scale, completely wiping out the plant before it arrives above ground, as soon as the surface dries out a couple of inches. Lack of humus is the trouble here as the humus and decayed vegetable matter should not only show as the tell-tale 'smudge', but would have kept sufficient moisture in the top soil, where the young roots feed, to allow the crop to reach the woody stage which the wireworm would not attack.

The answer therefore is to avoid the wireworm attack—since the pest cannot be eliminated—by managing the soil to allow both for humus in the top soil and easy capillary attraction (as has been detailed in Chapter V); and to sow early when the maximum amount of moisture exists and there is greatest likelihood of rainfall, as well as before the wireworm get really active—i.e. from the first to the last week in March. On cold soils probably the third or fourth week in March is early enough, but on warm soils earlier sowing is advantageous for other reasons, such as earlier harvest in hot weather.

Although perhaps it does not properly belong to this chapter something might be said here about drainage. In a previous chapter we have explained the 'water-table'. The height of the water-table in land should be such that it is just below where the roots of a particular crop reach. This level, while to some extent momentarily variable according to rainfall or melting snow, is finally determined by the water level of the surrounding land, river or ditch into which drainage easily takes place.

There is an increasing tendency to dig deep ditches round fields, an admirable practice in so far as it is intended to remove stagnant surface water: and a ditch should of course be clean. But observation shows that this ditch digging is often an haphazard proceeding since no attention is given either to the purpose to which the land is put nor to the resultant water-table.

Many pastures can be found with deep ditches at which cattle can water. Owners frequently complain that these pastures parch in dry spells. In many cases the grasslands have been laid down as permanent pasture many years ago and when some of them are ploughed up due to

war conditions it has been found that they have tile drains. These were at one time intended to remove surface water and, at the time they were laid, to let it fall into shallow ditches. They then probably fulfilled their purpose admirably. But because those ditches had silted up it was, in many cases, a mistaken policy to deepen them as well as clean them. The tile drains removed the surface water but they were above the actual normal water-table and therefore did not affect the latter. The ditch as originally made was only slightly below the drain outlets but did keep the water-table down to its own level by gradual seepage from the soil below the drains. Deepen these ditches two feet and in due course, during a dry spell, the water level of the surrounding land is lowered by that same amount and the subsoil water has that much further to climb before it reaches the grass.

In the case of arable fields, particularly where there is deep ploughing which makes the soil more porous, thus not only stopping the rising of subsoil water by capillary attraction, but allowing it to flow more freely laterally, it should not be very difficult to see that deep ditches will reduce the essential water-table level, often to a danger point, and double the damage that the deep ploughing has already done.

As the water-table level has so much to do with the moisture that the plant can obtain it has also a very considerable bearing on the possibility of wireworm attack. This question of moisture can be seen very clearly on sloping land where wireworm is prevalent and where wireworm attack is noticeable, since this land tends to drain naturally down to the lowest point. Every effort should be made therefore to conserve moisture particularly by additional humus. The final madness, of course, is to plough such land with the slope instead of across the slope, thus making additional natural gulleys down which the much needed water can run away. Yet we have recently seen land so ploughed by otherwise very good farmers who still wonder why their crops are so readily ruined by wireworm during a dry spring.

FLY

Fly will attack sunflower in the cotyledon stage. This attack is, from its season, more or less confined to the turnip fly or flea beetle (e.g. *Phyllotreta nemorum L.*). While the usual remedies may be applied if the attack is bad, it does not appear to do much harm to the plant. The cotyledons are not eaten right back to the stem and, in any case, it does not extend to the next leaves (third and fourth) which appear very rapidly at this stage. Any attack of this kind is usually prevented by mid-

March sowings when the cotyledon stage is passed before the time of possible attack appears.

BORING INSECTS

On very rare occasions we have found odd plants in a crop attacked by one of the boring larvae, such as that of the cabbage fly. But the stalk of the sunflower is usually too hard for these pests and it can be taken for granted that the plant attacked is generally one of delayed growth. So far nothing of a serious nature of this kind has been noted in this country.

GREENFLY (*APHIS*)

In some cases, particularly in dry weather, considerable colonies of greenfly will be found on sunflower. The severity of the aphis attack on any crop is seasonal. In the case of a severe attack the insects will damage the buds, particularly the main bud, causing malformation or even complete abortion. This may lead to multiheadedness or branching, a most undesirable state, since most of these so produced side buds never reach maturity by harvest time. Sunflower is exceedingly attractive to ladybird, large quantities of which will be noticed on all crops; it is, of course, a destroyer of greenfly so it is very probable that in general the latter pest is kept under by the ladybird. In other cases, fortunately, the greenfly may be parasitized before it has done irreparable damage. Appearance of ladybird does not necessarily indicate the presence of greenfly as there is some evidence that the former are interested in the resins and flower exudations.

If greenfly are found in only small quantities it is best to leave well alone if ladybirds are present. Only in case of a severe attack should recourse be had to spraying or dusting.

BEETLE

One crop in 1943 was attacked by *Gastroidia polygoni*. The damage was in the cotyledon stage. Dusting stopped the attack. Extensive attack of any crop by this beetle is rare.

NEMATODES

The roots of the plant may be attacked by nematodes of the eelworm type, such as are often found in clover crops, and oats. While something

can be done to cure this in the way of 3 cwt. of sulphate of potash per acre (not advisable for sunflower for reasons stated elsewhere under 'Fertilizers') or 2 cwt. of sulphate of iron, prevention is better than cure. Avoid growing sunflower and clover in rotation or even after oats if there was an eelworm attack in the previous crop—this is obvious. Prevention of eelworm is best assured by the incorporation of plenty of dung or other rotting vegetable matter in the soil. Many of the micro-fungi bred on such matter are themselves rapid killers of the nematodes.[1]

LEATHER-JACKET

This old friend, the larva of the daddy-long-legs or crane fly, is usually an inhabitant of grassland and may therefore be looked for in newly ploughed land, particularly if the latter contains much tussock grass. It is of course also found on land that has grown cereals. The maggots hatch out in a week and commence their boring work. Generally sunflower reaches far too woody a stage for the larvae of the crane fly to attack, but where growth has been delayed by dry weather attacks have been known, particularly where large pieces of unbroken turf, in which the eggs can be laid, remain on or near the soil surface. It does not appear that the eggs are actually laid on the sunflower so that no serious attacks of this pest have been noted.

As with cereals, early sowing is again advisable and the thorough disking and breaking down of turf.

CUTWORMS AND OTHER INSECTS

Cutworms are mentioned as liable to cause damage in Canada and U.S.A. and, though we have as yet had no trouble from these in Britain, the possibility exists. Cutworms are the larvae of various kinds of moths and are, of course, well known to the British farmer as attacking many crops and are chiefly traced to weedy land. For methods of control see Ministry of Agriculture Advisory Leaflet No. 225. There is no doubt that other pests such as certain beetles might be found destructive to sunflower in certain stages should they appear in sufficient quantities.

SLUGS

In some districts slugs may be very damaging though generally speaking these should not exist on well-drained, well-cultivated arable land,

[1] See *Biological Review*, Vol. 16 (1941), pp. 278, 290.

unless they come from the hedgerows on the borders of a crop. Lime and soot tend to remove these pests where they exist.

Where, however, sunflower crops are grown in gardens or small allotments slugs may be more prevalent and the necessary steps should be taken to catch or destroy them. In late districts those growing small plots may be advised to sow rather later, say the end of March or first week in April, when the warmer weather tends to keep the slugs to the grass or shaded places rather than the bare ground.

PARTRIDGE AND PHEASANT

Many farmers rightly regard both these game birds as pests and as such they are not desirable on any agricultural land. Their depredations can cause very heavy losses. This is particularly so in the case of sunflower. The sunflower shoot comes out of the ground with the seed still attached and it is this the bird goes for. Unfortunately in taking the seed he breaks off the small stem thus entirely killing or at least ruining the plant. It is perhaps not here that one should give a remedy, though several exist which are probably well known to farmers. As to how far this damage can go it is only necessary to say that in one case nearly ten acres of sunflower, just through the ground, were taken in a week, where the land adjoined a sporting estate. Pheasants seem to ignore sunflower once it has passed the cotyledon stage and where pheasants abound April sowing is advisable.

PIGEON

The pigeon is a curious bird in regard to his feeding habits as, just as he is sporadic in his visits, so he is uncertain in his depredations. In several cases we have seen sunflower attacked by pigeon, though in only one case at the stage where it is attacked by partridge. On the other hand we have had as much as an acre of sunflower more or less ruined in a very short time by pigeon which picked out the centres, when the plants were about a foot high. This appeared to be merely mischief as the nipped-out centres were not eaten. The plants were not destroyed but they branched out into many small heads. As these heads do not ripen at the same time, and therefore only a few can ever come to maturity, the resultant crop is considerably lowered, apart from the additional labour involved in cutting heads. The pigeon of all the birds in this country is probably the biggest pest to-day and the smallest use, so that no excuse seems to exist for allowing him to multiply as he has in recent

years. The probability is that the pigeon has flourished due to the attacks we have made on his enemies of the hawk family. If this is so what the hawk has taken in the way of game birds and chickens, as an addition to his diet of mice, rats, etc., is in no way balanced by the enormous bill we pay yearly in maintaining the pigeon. It never pays to upset the balance of nature and we should be prepared to feed some of Nature's army if they compensate by their riddance of greater pests.

ROOKS

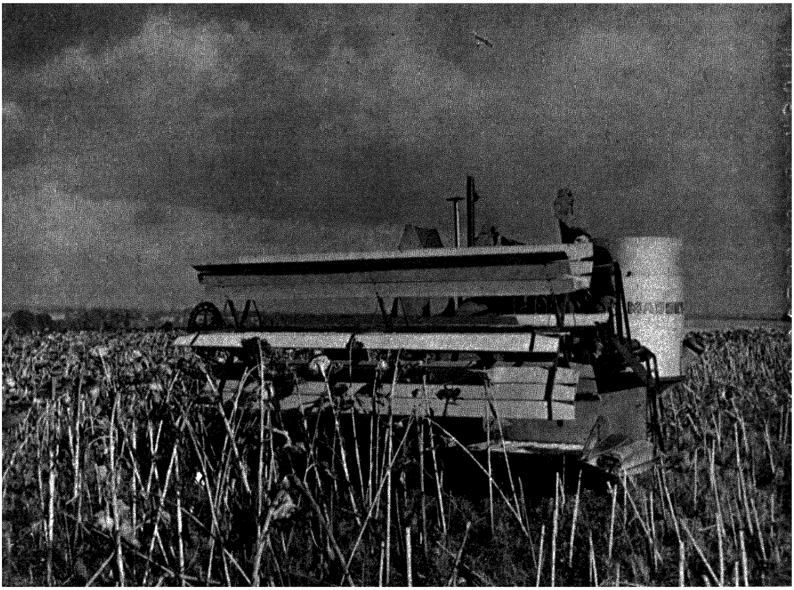
So far there is no evidence that rooks have attacked sunflower for itself and where cases have occurred of rook flocks pulling young sunflower out of the ground, it has always been found that the crop was already attacked by wireworm. This therefore is only another reason for getting crops early away before the wireworm are active and the rooks seeking insect food for their nestlings. Rooks will not attack sunflower except in the early stage.

It is worth noting here that rooks will not settle direct on a crop. They alight first on open land outside the crop or on bare patches within the sown area and work their way inwards on the ground. It has been found that loose string on low stakes round the crop or stringing over the bare patches almost invariably wards off rook attack. As an additional precaution occasional use of string, tied in loose loops, that will swing in the wind, to eight-foot poles, across the crops, is advisable.

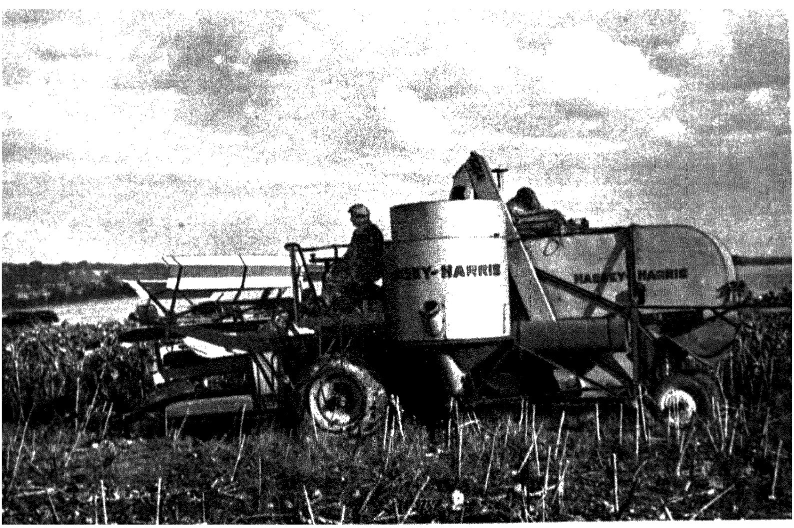
FINCHES

All finches like sunflower seed, but only the greenfinch flocks in sufficient numbers to cause appreciable damage.

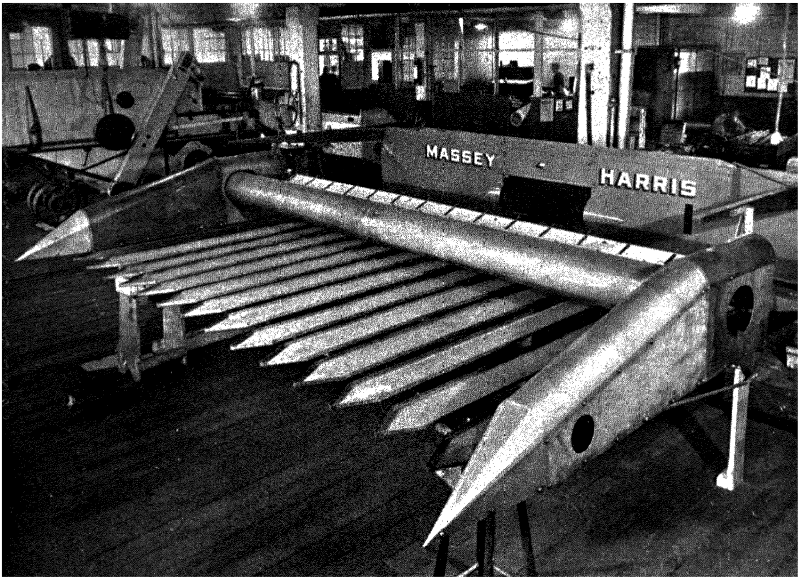
Greenfinch population is migratory and sporadic and therefore cannot be anticipated. Flocks of greenfinch may consist of 100 birds or so or several thousands. Even large flocks will not necessarily attack a crop of sunflower and we have evidence of three crops within a radius of a mile, consisting of one, two and four acres, all of the same variety. Practically three-quarters of the yield of the one-acre crop was taken before it was ready to harvest, while neither of the other crops seemed to attract the birds. This called for further investigation and it was noticed that in all cases where greenfinch attack was serious the crop was either surrounded by high hedges or had overhead cables running across or alongside it. The cables and the hedge seemed to give a look-out vantage point for sentinels of the bird flock, from which they could signal the approach of



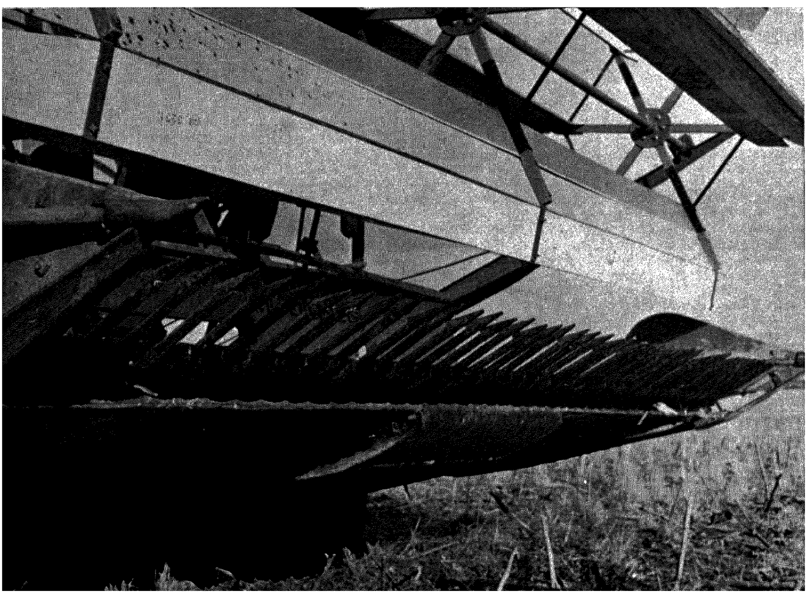
11 (*a*). Massey-Harris No. 21 Self-Propelled Combine, harvesting sunflowers near Winchester 1944



11 (*b*). Massey-Harris Self-Propelled Combine, harvesting sunflowers at Stoke Charity, Hants, 1944



12 (*a*). Massey-Harris Combine 'comb' attachment as used for sunflower crops in America



12 (*b*). Massey-Harris Combine Harvester showing special long fingers and the built-in sails, necessary for dealing with sunflower crops

danger in the form of human beings. Both the cables and the hedge seemed to be regarded as ample temporary safety for the disturbed flock until all was 'clear' again, when they swooped back to their feed. For these reasons it is certainly inadvisable to grow sunflower near cables or tall hedges. If one must, the use of a rope-'gun' has been found effective, though several of these are necessary on a large crop.

It will, however, be seen that a small plot of sunflower, such as might be grown on a smallholding for poultry grain, can be almost entirely taken within a few hours, if a large flock of greenfinches decide to attack and precautions must be taken against this. Sunflower crops near stackyards and in built-up areas are more prone to bird attack.

It is pointed out in Canadian advisory leaflets that on the prairies and open park belt there is little or no loss from birds, which bears out our suggestion that sunflower is not only to be kept away from built-up areas and stackyards but has a better prospect in open country free from woodlands.

Normally we aim to select seed from plants which tend to droop their heads as seed ripeness approaches—as the flowers fade and the florets fall. This is for two reasons. First such plants then get the full rays of the sun on the back of the head, hastening the drying and ripening process. Secondly they are less prone to bird attack as the finches can only feed either by sitting on top of the head rim and picking out the upper seeds or by perching on a projecting leaf stem below. If such heads are being attacked it is worth while going through the crop and brushing off, with the hand, the leaf immediately below the head. The stem is very brittle and knocks off very easily and even a large crop can be done as fast as one can walk through it.

Certain plants are apt to sport and form heads, with thick necks, which either do not bend over at all or else stand horizontally facing the sky. The former are easily attacked by birds and the latter are perfect bird-feeding tables from which all the seed will be taken forthwith. Such plants should be rogued out as soon as their formation is seen, before pollination takes place if possible, to prevent reproduction.

Bird attack takes place at a fairly early stage, just after the outer petals have faded and the florets on the outer rings have dropped off, exposing the seed. From then on to the time of harvesting the sunflower is vulnerable to finches. Undoubtedly, however, specific loss from finches will be minimized once crops are grown on a considerable scale, when the supply of sunflower seed will be greatly in excess of bird demand.

SCLEROTINIA DISEASE

There are only two diseases of a fungous nature which appear to cause any trouble on sunflower crops in this country at present. One of these is Sclerotinia, a disease caused by the fungus Sclerotinia sclerotiorum (Lib.) de Bary, which attacks a large number of crops, especially those of a pulpy nature such as potato, tomato, carrot and bean, as well as weeds like groundsel, chickweed and convolvulus.

The fungus attacks the stems near ground level or even below it, passes through the stalk and consumes the pith. In the cavity so formed, and frequently on the outside of the stem or root, a fluffy or wad-like mass of white mould is produced. In the latter the resting bodies (sclerotia) of the fungus are embedded. These resting bodies are firm and black, varying in size from a pea to a large bean (see photo A). As the disease progresses through the stalk the leaves begin to wither and finally the whole stem dies.

In another form of this disease which has been noticed the plants turn gradually black, mildewed and rotten in the upper portion, with the formation of conspicuous sclerotia, especially in the pith cavity (see photo B).

The sclerotia, or resting bodies, ultimately fall to the ground or reach the soil from the pith cavity as the stems decay. But they remain alive in the soil until early the following summer when many of them germinate to again produce spore-bearing bodies. The spores so produced are blown about by wind or carried by insects or other agencies and they serve to start new infections. Probably, however, more often infection takes place from mycelium formed directly from sclerotia present in the soil.

Affected plants may either be isolated units throughout the crop or may appear in groups. There is little spread from plant to plant during the season. Watch should be kept for affected plants and these should be destroyed by fire before the sclerotia are released. Otherwise the latter will lodge in the ground to affect any succeeding crops that are potential hosts as mentioned previously. Ploughing or cultivating breaks up and further distributes the sclerotial masses over a wider area. As the sclerotia can remain alive in the soil for more than one year it is not advisable to grow sunflowers within two years of any crop that has shown an appreciable attack of this fungus or on land where weeds so attacked have been noted. It is well to remember that sclerotia may be carried *in or among seed* if infection occurs on the head at or near the ripening stage.

BOTRYTIS OR GREY MOULD

The other disease frequently found on sunflower is caused by the fungus Botrytis cinerea Fr., which produces a dense brownish-grey mould on the outside of the parts attacked. Botrytis is an exceedingly common fungus of a very minute type which lives on all kinds of dead or decaying vegetable matter. It is frequently found as a brownish-grey mould on damaged fruit. It produces millions of spores which are carried about among the crop by wind. While Botrytis can be found at almost any season and grows equally well indoors or out, provided conditions are moist, it does not confine itself to dead matter but may attack and rot living plant tissues. While it chiefly attacks the head, where, of course, it is most damaging, it will not attack healthy growing and undamaged parts of sunflower. Therefore, except where it can find an entrance on an unhealthy plant or a damaged portion of a plant, there is little danger of attack until the head begins to ripen and ceases to grow—in other words at the stage of impending death of the tissues of the plant as, its function over and the seed fully ripe, the drying process is going on. Botrytis however needs a moist atmosphere and, except in a very wet season, its incidence of attack is unlikely until early autumn when we get damp nights, morning mist or fog and insufficient day heat to dry out this moisture and kill the fungus or prevent the spores from germinating.

It is not a case of cure but of prevention. The most usual attack, when it comes, is found on the back of the head, either while the ripe plants are standing in the field or while they are stooked or fenced for harvest. Probably many readers have grown sunflower in their garden and kept the heads for seed for resowing or for poultry feeding. They will undoubtedly have experienced many times this 'mildewing' of the heads, due to Botrytis, if these have been stacked or laid together or even kept in an airless room or greenhouse. In such cases, if the harvest is late, to avoid Botrytis, it is essential that the heads should not touch one another after cutting, preferably be hung up, and a current of dry air allowed to circulate round them.

We largely avoid Botrytis on field crops by early sowing so that our crops are dry enough and ripe enough to harvest before the damp nights and the days with lack of heat arrive.

It is still possible that a few heads may show signs of Botrytis due to faulty stacking while drying in the field, where there has been lack of air circulation or too close contact between the heads. No damage is done provided the fungus has not attacked the seed. Even then, of course,

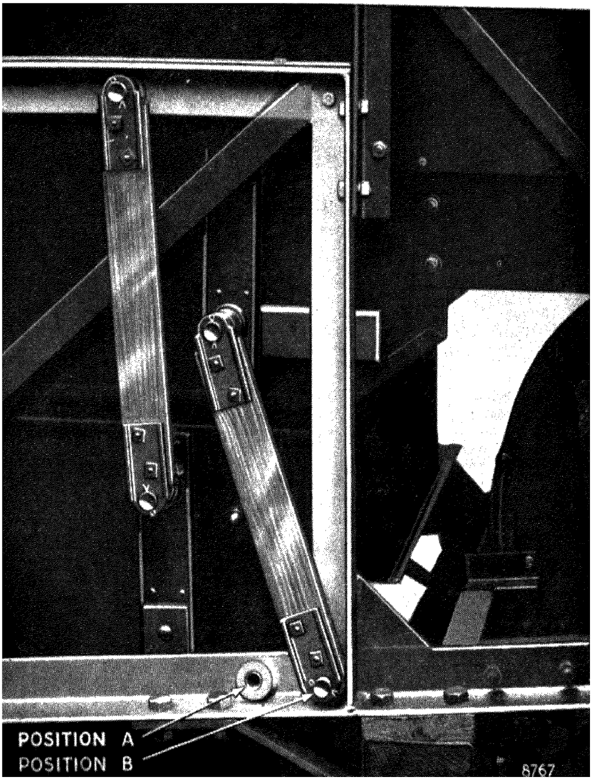
in threshing, spores will fall on the seed and if the latter is not thoroughly dried forthwith these spores will germinate and the seed be mildewed and spoilt. In such cases it is most certainly advisable, unless it is possible to spread the seed thinly in fresh air currents and a warm room or the sun, to dry artificially, both to remove surplus moisture and kill the spores.

Botrytis is usually accompanied by other species of fungi.

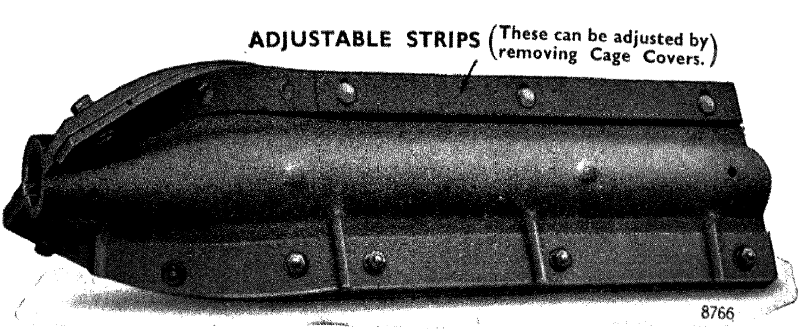
RABBITS AND HARES

Rabbits, like many other animals, like sunflower foliage when young. It provides a very fine food for them as does also the milled meal made therefrom. So it is only natural that wild rabbits will eat the young plants. Attention should therefore be given either to the reduction of the rabbit population, if any exist on the farm, or to netting to keep them off the field. Of course, rabbits as a rule only eat the crops nearest to the confines of the field.

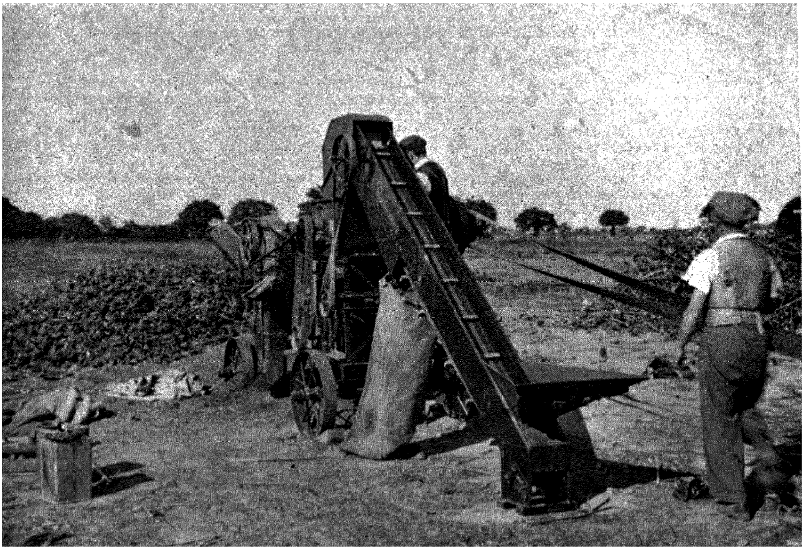
One case was brought to our notice where hares destroyed the greater portion of a three-acre crop. It seems, however, that both the rabbits and hares are more likely to attack in very dry weather when other food becomes largely sapless and fibrous.



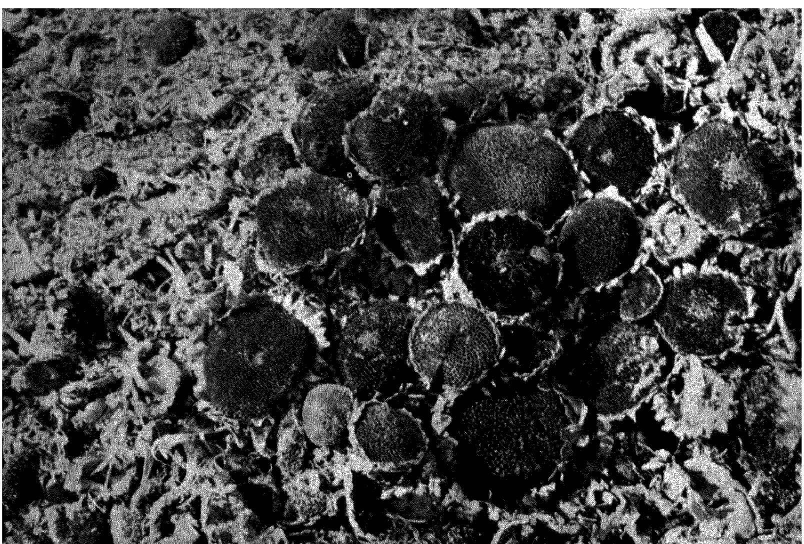
13 (*a*). Adjustment to Ransomes Sheller



13 (*b*). Adjustment to Ransomes Sheller



14 (*a*). Ransomes Sheller. Blower tube attached, on well-dried crop



14 (*b*). Deseeded heads, practically unbroken, from a Ransomes Sheller working on a well field-dried crop with low moisture content. Variety Southern Cross

CHAPTER VIII

HARVESTING SUNFLOWER

TIME TO HARVEST

It is more important to select the time when the seed kernel has attained its maximum growth than to hurry harvesting. Sunflower seed does not shatter or shed easily, particularly when the plant is still standing, so that there is little danger in that direction in leaving the harvesting after full ripeness stage has been reached.

About three weeks after the large petals round the head rim have faded it will be found that the florets on the seed face begin to loosen and can be brushed off with the hand. It is, however, not until the florets covering the central ring of seeds—a ring having a diameter of about one and a half to two inches usually—are similarly quite loose that the ripe stage has approached. Although maximum kernel growth has been reached at the time when these florets die, it is not advisable to consider harvesting yet since the seeds at this stage contain about 50 per cent of moisture and the lower the moisture content the easier the harvesting, threshing and drying problems.[1]

The heads are ripe before the leaves commence to wither. Once the central florets loosen the next sign will be the weakening of the neck and, in normal plants, the bending over of the head, which simultaneously will begin to turn in colour from green to yellow. Following this the leaves will commence to fade from the bottom up. Any time now harvesting can take place but, where the crop is sufficiently early and the weather hot, it will be as well to leave the heads to dry out still further before cutting. Under the most favourable conditions the heads will dry down to a very low seed-moisture content on the standing plant, and neither 'stooking' nor 'fencing', described below, will be necessary.

The lower the water content both in seed and in the flesh of the back of the head the easier the threshing and the less likelihood of need for artificial drying. Given early sowing and good drying weather in August, moisture in the standing crop will drop from 40 per cent to 20 per cent or even 16 per cent.

The necessity of ensuring a stage of complete ripeness is most important. This stage implies that the kernel has attained its maximum oil

[1] See 'Ripeness', Chap. IX.

content. Before that is attained the husk may appear to have a full kernel but there will be considerable excess water both here and in the husk cells and this moisture will be lost when the seed is dried, the ultimate yield being dependent on kernel-oil content. It has been shown that during the last fortnight of ripening the increase in seed weight can be from 50 per cent to 100 per cent, so that it is better to err on the right side rather than harvest too early.

HAND CUTTING

When it is considered that cutting should take place, the stalks are cut about three inches above the ground preparatory to the second stage of field drying. The best instrument for cutting is an ordinary, heavy butcher's knife. This is light enough to wield without fatigue and is less dangerous than a sickle. The stems are tough and need a good blow in most cases and, with a sickle, there is always a danger, should a stem yield more easily than anticipated, of impaling one's leg.

FIELD DRYING

As far as possible an attempt should be made to dry out as a standing crop. But when this is not possible there are now two alternative methods of procedure. One is to 'stook' and the other to 'fence'. The choice of method depends entirely on local conditions.

STOOKING

Owing to the risk of mildew where plants are bundled together and to lack of air circulation necessary for the drying of the heads, tying in sheaves is not advisable with a moisture content over 16 per cent.

Wooden tripods or contrivances such as those often used for beans and hay in Scotland, make excellent bases on which to pile the plants. Without these, however, quadripods can be made with the plants themselves by the following method. Select four strong stalked plants and with a length of some eight inches of binder twine tie two of these tightly together about eight inches below the head so that the stalks are at about 45 degrees to the ground. Take the second pair and tie these together at right angles to the first pair, whipping the twine round the joint of all four. If the bases of the stalks are firmly planted on the ground one then has a firm quadripod (see figures). It is important that the tie should be at least seven or eight inches below the head as the neck will bend and become pappy as drying proceeds so that a tie *on* the neck tends to

loosen and the whole quadripod collapses. The stalks must be tied so that the heads face the ground, thus keeping the rain and dew off the seed face and enabling sun and air to dry out the back of the head.

Now lean further plants against and around the quadripod. As heads should not overlap and seed faces must face inwards it may be necessary to shorten some stalks so as to get a staggering effect (see photograph). The number of plants which can be piled against one stook depends entirely on size, weight and strength of the quadripod, but generally from twelve to twenty. A little practice shows that with one cutting the plants and four stooking (two persons to a stook) about half an acre can be dealt with in four hours. As drying proceeds and after a few days the leaves will completely wither or fall, allowing full air circulation in the stook.

FENCING

This is an alternative method to stooking and probably far to be preferred from the labour point of view, if suitable appliances are at hand. The method implies the laying of the plants on fences or rails about thirty inches above the ground.

Sheep hurdles make admirable fences as do poles or old iron pipes raised on tripods. Alternatively wire can be stretched between posts but the wire must be strong as it should be realized that there may be up to sixteen tons of plants per acre. The posts required for stretching the wire must also be very stout and well embedded in the ground since it is desirable to stretch the wire by tractor. It is generally advisable to put in the posts early in the season while the ground is soft enough to get them in deep. Often, of course, a convenient tree at either or both ends of the field can be used. The wire will stretch in any case and should therefore have some support every ten to fifteen feet. The supports can be by way of tripods, further posts or old potato boxes. To take the 'pull' and avoid uprooting, lean *end* posts outwards and fasten wire to *base* of these.

To stretch the wire between the end posts, cut one or two rows of plants to form an alleyway for the fence.

On this fence it is proposed to stook ten rows of plants, that is five from either side. The first row is placed so that the heads hook over the wire, seed downwards, and the same is done with the first row from the opposite side. This will leave the stems on either side inclined at roughly 45 degrees with the ground. Subsequently second layers are laid on either side so that the heads rest below the first heads in a slightly staggered position, supported on the first stalks. And so with the remaining three rows on either side.

The length of fence required will depend on the variety of sunflower, the spacing, head size, etc., and probably sheep hurdles will take a larger quantity than wire. But approximately 150–200 yards of fence will be sufficient for an acre.

Under good drying conditions the heads will rapidly lose moisture in the stooks or on the fences. Under ideal conditions it has been found possible to reduce the moisture content of the seeds as low as 14 per cent in which stage the backs of the heads are shrivelled, brown and brittle and the seed threshes out very easily by any method. The time required in the stooks will vary from ten to twenty-one days. Partly due to the position of the heads and also on account of the oil content, it will be found that while rain will delay drying it will not add to the moisture content.

The heads should not be allowed to dry out too completely as there may then be risk of shedding and loss of seed in handling. But if drying can be got down to, say, 16 per cent to 18 per cent moisture before threshing there will be no need for artificial drying of the seed.

MACHINE CUTTING

While under conditions obtaining in East Anglia and some of the southern counties, combine harvesting has been shown to be a solution and has been satisfactorily carried out, it seems that some method, more suitable for the districts where a low enough moisture content in the standing crop cannot be normally depended on, will have to be found. This should come from the evolution of a cheap machine, on 'header' lines which will cut off the heads, collect and deliver them into a trailing vehicle over a canvas conveyor. Either of these methods is desirable to obviate the labour required in stooking and fencing, especially should the world price of sunflower reach a somewhat low level, when grown on a wide commercial scale. The latter machine would be usable where crops were insufficiently dry for threshing in a combine harvester. The method of 'pick-up' and cutting would be similar to that employed on combine machines abroad, using the necessary fingers, sails and cutter bar.

Combine harvesting is, of course, largely practised in the dry localities of U.S.A., the Argentine, Canada, etc.

THRESHING MACHINERY

Naturally in a few years it has not been possible to try out all types of

threshers available in this country. The utility of most threshers depends largely on the dryness of the heads.

With *very* dry heads it is possible to thresh satisfactorily with grain threshers of the American rasp bar type, provided the drum speed is reduced to about 425 r.p.m., most of the concave bars removed, and the drum set wide. Some other threshers of the peg drum type are also suitable with well-dried heads and appropriate adjustment. Under similar dry conditions drums of several British makes could probably be adjusted or slightly modified to make them suitable for sunflower.

Messrs. Marshall, Sons & Co. Ltd., of Gainsborough state that large quantities of sunflower were threshed by their machines in Russia and Poland and give the following instructions for the necessary adjustments for this crop:

(*a*) Use a standard thresher of the beater drum type. Set the top of the upper half of the concave right back, the centre and bottom of the concaves to be set off to suit the thickness of the heads of the sunflowers; there is ample allowance in the adjustment to enable this to be done.

(*b*) Fix a bean plate on the top half of the concave.

(*c*) Use oat riddles in the machine and adjust the blast and tail boards to suit seeds.

(*d*) It is necessary to pass the seed direct from the elevators to the second dresser riddles. Do not pass it through the awner.

But none of these drums is suitable for undried heads, such as must be tackled in the case of a later crop, nor with heads which contain much over 16 per cent of moisture, as the majority are liable to split the seed or even to decorticate it under such conditions.

Of the machines that have so far been tested the best is a modified type of maize sheller, manufactured by Ransomes, Sims and Jefferies, and largely used for maize in South Africa. This machine has given excellent results with seed of up to 45 per cent of moisture, making a clean sample with no broken seed, and removing quite 90 per cent or more according to the state of moisture. Weighing only 21 cwt. it is easily taken about. While this machine is suitable also for maize and certain other crops, such as leek and onion seed, it is not adaptable for grain. This sheller will not take the whole plant and it is therefore necessary to remove the heads before feeding into the elevator hopper. It should be noted that with dry heads the sheller throws out the deseeded head intact and produces a very clean sample of seed. But with moist heads these are broken up and considerable quantities of very small pieces of wet head and damp florets pass the screens and blower and come out with the seed, so that further cleaning has to take place during or after drying.

The elevator feed hopper of the Ransomes 'sheller' can be fitted with two sets of heavy knife blades of a special pattern for cutting maize cobs from the stalks. Where a sunflower crop is threshed on the field these are great time savers. Bundles of some four to six stalks are held by the man feeding the hopper and a single 'drawing' blow will decapitate the bunch allowing the heads to fall directly on the elevator. This is quicker and needs far less labour than removing the heads by hand and taking them to the sheller. Both sets of blades can be used simultaneously where two men are feeding.

Some of the combine harvesters can be used for threshing really dry (dead ripe) crops. In this case the speed of the operation is far slower than the sheller but the whole plant can be fed in. The extraction in this case is up to 95 per cent. With a dry crop a Ransomes sheller will thresh about one acre per hour, two men to feed and one to bag off.

USING RANSOMES SHELLER

When threshing with the Ransomes 30-inch Sunflower Sheller, certain adjustments must be made according to circumstances.

Speed. Under most circumstances the normal speed required on the helice (driving pulley) is 910 r.p.m. With some varieties, especially under very dry conditions where a large quantity of material is being passed over the top screen and consequently some seed is found to be passing into the refuse blower, it may be found necessary to slow both the feed and the speed. It is impossible to give exact instructions as to this, and speed, etc., must be adjusted by trial according to particular circumstances. In general, however, interchange of screens or alterations of air blast will take care of varying conditions.

Top Screen. By means of a blanking plate at the rear of the top screen, the actual area of screen surface can be adjusted and with wet crops, where much broken head is coming out of the drum, the fullest screen area is advisable. In general two types of screen are supplied, one with round and one with slotted holes. The alternate use of these screens will depend largely on the condition of the crop and the size of seed being threshed. Usually for moist crops the round hole screen is best. Interchange of these screens is quickly made. Ploughs—five in number—are supplied for use with the slotted screen and the use of these is to turn the deseeded heads if the latter are found to be carrying away seed on their surface. If the ploughs are to be fitted circumstances must dictate as to whether three or five are fitted but in any case the three ploughs should be fitted in one row near the front or refuse end of the screen. If

five are found necessary the other two should be fitted about four inches to the rear of the first three. For the larger seeded varieties the slotted screen has often been found most suitable and with dry crops ploughs are not needed. It will, however, be found that if the crop is carelessly cut, with more than a few inches of stalk, whatever its moisture condition the omission of the ploughs is best, as otherwise the stalks are inclined to hook on the ploughs and form a dam.

Suspension. The suspension of the upper shoe from the forward position, as shown in Ransomes' diagram in their instructions, provides a more violent shaking motion to the top sieve and is *always* advisable in threshing sunflower.

Second Screen. This dressing screen is in two portions for easy removal and the front portion is adjustable for tilt. In most cases it is best to lift the front end as high as possible to hold seed on as long as possible and prevent it flowing over the front, depending on the fan blast for removal of chaff. With a very wet crop exact adjustment may be impossible and one has to consider whether it is better to carry some seed over the front and put the carry-over across the top screen again later or to allow an excess of small pieces of head to come through the outflow into the bags. This depends on the dryer to be used and its capability of dealing with this moist head waste and also how long the seed may have to be kept in bags before being put into the dryer. Dryers with grain hoppers and wooden elevators are liable to cause feeding trouble if an excess of head is passed through with the seed and to jam entirely if the mixture has been allowed to heat.

In the case of dry crops it may be found that considerable quantities of chaff fall with the seed from the upper screen due to overloading by rapid shelling. Four dressing sieves are provided. If the above occurs it may mean that seed is passed over the front of the dressing screen because the mat of chaff has prevented it reaching the holes. In this case mount the larger holed pair of sieves over those with smaller holes and so obtain double dressing surface with better separation. This double-tier screen arrangement is usually advantageous with all sunflower crops.

With a wet crop constant cleaning of the second screens is necessary. This can be effected while the sheller is running by means of a small hoe used to scrape the screen surface and keep the wet mass from clogging the screen holes.

Lowest Screen (Dust Screen) and Seed Outlet Screen. The former is easily removed by means of the two hand levers. It may need frequent cleaning with a wet crop. With a dry crop fine pieces of fibre are inclined to block it. In the latter case passing a sharp knife at intervals over its

under surface, so cutting the fibres that are half-way through the holes, will usually keep it clear without stopping the machine. The last outlet screen draws out and may need to be cleaned during operation on a wet crop due to accumulation and matting of floret dust.

Fore Blower Tube. This is intended to be used to direct waste outlet and so spread the waste heap and also in case of cross wind. It should not, however, be used with a wet crop as the deseeded heads are resinous and sticky and will frequently entirely block the tube and cause compulsory stoppages of the shelling operation.

Drum. With all types of crop it is essential thoroughly to clean the drum cage, cage box and all screens *every night* when ceasing operations. This is particularly the case with a wet crop as resinous waste will set hard overnight and cause very considerable trouble when next the machine is used, apart from being far harder to remove. Generally, cleaning can be done with a knife and the hands, but the use of water pressure from a hose will make a better and more complete finish.

Both wide and narrow strips are provided for the helice in the cage and, when threshing sunflower, the narrow strips are used to allow for the thickness of the head and prevent decortication.

Maintenance. It seems unnecessary to state that attention to all nuts and bolts should be a matter of constant supervision. The shaking motion tends to loosen the adjusting bolts on screens, as well as elsewhere, and even the axle nuts have been known to come off. Where nuts work loose the use of spring washers and double nuts is strongly advised if the makers have failed to provide them. On no account walk on the top screen, though the flat metal surface in front of the drum box will take the weight of a man for cleaning purposes.

Belt Drive. The belt can be driven from a tractor at either end of the machine and for feeding purposes it is more convenient to drive from the front end, allowing easy access to both sides of the elevator hopper. But in that case use planks or screens of some kind to direct the waste off the tractor. In the case of a cross wind blowing towards the tractor, when threshing a dry crop, the drive should always be taken from the rear, even if the belt has to be crossed, as dry matter of sunflower is inflammable and may easily catch alight from the hot tractor exhaust pipe and perhaps start a serious fire in the waste heap or the tractor itself.

Feeding the Hopper. Having assured oneself that the hopper is level and made the necessary adjustment to allow the elevator belt to run centrally, without fouling the hopper box sides beneath, it is only necessary to see that very large heads are cut before being fed to the belt.

Very large heads on a wet crop will jam at the top feed box and become a nuisance.

It is a saving of time to place heads seed downwards on the elevator rather than throw them in indiscriminately in the case of a wet crop. The latter method tends to induce jamming in the entrance to the cage. With a very dry crop this is immaterial and, provided no long stalks are present, jamming is unlikely to occur.

For other instructions see leaflet provided with the sheller.

Note: (1) If in spite of the above suggestions, due to overloading of screens from one cause or another, seed seems still to pass either across the top screen into the refuse blower or over the shaker riddles, it is worth while raising the fore part of the sheller slightly so as to keep the seed rather longer on the riddles. This can be done either by means of wooden blocks under the front wheels or by sinking the rear wheels slightly into the ground. (2) Heads cut with too much stalk will be a general nuisance. The stalks may interlace and jam at the entrance to the cage or top of elevator. They will also tend to lace themselves in the cage bars and so block seed outlet, causing de-husking. This is particularly the case with all but really dry crops.

WET CROPS

It has been said above that the sheller will thresh heads cut direct from a standing crop, with up to 45 per cent moisture, thus eliminating the need for stooking and drying. This, however, is not a desirable proceeding as it involves immediate use of a suitable dryer, since moist seed heats within twelve hours or less and, as will be explained later, many dryers suitable for grain are totally unsuited for sunflower. In any case to dry sunflower seed with a high moisture content it is necessary to pass the seed more than once through the dryer and there is some difficulty in getting a clean sample. Furthermore it is impossible to use the deseeded heads from a damp crop for anything but silage or manure since they will heat at once and ferment. The making of feeding meals is unpractical in this case, the protein, if not all digestible food constituents, having been destroyed.

Note. The artificial drying of green heads with the seeds in is an impossible proposition. The application of artificial heat to such causes first sweating and then sealing of the cells. Satisfactory drying thus would entail continual alternate cooling and heating and unless the heads were spread in a single layer with a satisfactory air current rapid deterioration—rotting—and Botrytis will follow.

HAND THRESHING

This is only practicable with small crops and the heads must be dry if this is attempted. In this case the seed can be threshed out either with a flail, by knocking the heads against the sides of the interior of a barrel, or by rubbing the heads across tables, made with a sheet of expanded metal, or very fine mesh wire netting, stretched over a frame raised to a convenient height. Dry the seed in a thin layer on a dry, airy floor and winnow well before bagging.

COMBINE HARVESTING

Sunflower, on large acreage plots, has been successfully combine-harvested in this country, the necessary long finger attachments to the cutter bar having been imported for the purpose. It seems a perfectly feasible proposition in those districts, such as East Anglia and some of the southern counties, at any rate where climatic conditions allow the crop to be dried down sufficiently in the field to be dealt with by the combine threshing drum,[1] when suitably adjusted. Combining is done in America, particularly in the Argentine, where several types of local make, as well as American (U.S.), combine harvesters are used. The special finger or 'comb' attachments draw the heads under the sails and to the cutter bars. The trials carried out here have been made with such machines as the Massey-Harris, much used abroad, and the Allis-Chalmers model '60', fitted with high-lift headers and bundle toppers. Finger attachments should point slightly upwards so that cut heads are guided to the platform. If the fingers have ball ends any tendency to impale the plant stems is avoided.

The use of fine mesh wire netting or 'expanded' metal sheet on the existing reel is always very advisable, though it should have a mesh of less than one inch and be of heavy gauge. The object of this is to present a more or less solid reel without which there is considerable loss of heads and seeds due to the former hooking over the normal reel slats and being thrown clear of the combine. The wire netting method may be most desirable as it presents less wind resistance than a solid board reel. Should it be found that the reel strikes the heads sufficiently hard to throw them clear of the combine the speed of the reel should be reduced

[1] The top plant leaves must be dry and shrivelled, by which time the backs of the heads are turning yellow brown, before combine harvesting is attempted. The heads are now stiff and spiky to the hand and much of the seed is probably free of florets.

by 50 to 60 per cent below that used for cereals, though on a four-bat reel it may be necessary in this case to increase the number of bats to six. Where extra slats are added as an extension to the normal slat the former should be set at an angle of 30 degrees from the reel arm, pointing in the direction of rotation so that the extension hits the head just before decapitation. If stalks are struck too far in advance of the cutter, seed is shattered and lost. The centre of the reel should be well above the tops of the growing heads to avoid breaking the stems. Too high setting, however, will take the reel sweep too far from the knife. Although some other adjustments or modifications may be necessary in accordance with the spacing or condition of a given crop the makers of the combine machinery are quite capable of giving advice or making the necessary alterations.

If heads cut by the extremities of the knife tend to fall clear because they do not contact the reel, extension dividers, of flat iron, pointing slightly inwards, can be added to guide plants on the extremities away from the machine. On some makes, especially those lacking in a 'high lift' and therefore cutting a considerable stem length, the same result is obtained by building up the sides of the combine frame with metal sheet.

As general instructions for the use of combines on sunflower crops it is, of course, necessary that the concaves should be opened as widely as is necessitated by size and average thickness of head in each variety, and the drum speed reduced to about half (viz. about 600 r.p.m.), that used for wheat or oats, though normal speed must be used elsewhere to ensure the carry over of the refuse. Almost full wind can usually be given. With proper adjustment a very clean sample of seed can be obtained though in some cases it may be necessary to rewinnow to remove some blind seed found in the centre of the heads of most varieties.

Drum speeds are most satisfactory between 385 and 600 r.p.m., according to make of combine, higher speeds being possible where rubber beater bars are employed. Too high speeds crack the husk and skin the seed. Excessive return of tailings to the drum also produces cracking. Clearances $\frac{1}{2}$ inch to $\frac{3}{4}$ inch are necessary and most concave bars are best removed.

It is frequently advisable to substitute a round holed sieve for the bottom adjustable one.

In some cases it has been reported that there has been difficulty either with the clogging of the straw walkers or on the conveyor from the cylinder to the walkers, where the latter is at a steep angle. The former difficulty should not occur where the crop is sufficiently dry and, in any

case, slight speeding up of the walkers themselves should overcome it. Where the straw goes direct from cylinder to walker the second difficulty will not occur and where it does in certain types of machines it can usually be traced to inefficient adjustment of the feeder conveyor.

Tests here and in Canada show that combines with canvas tables have advantages over those with auger platforms as the latter tend to throw the heads clear and there is some liability to jamming.

Though at the time of writing the Self-Propelled Clipper type of combine has not been tried out in this country it has been most successful with sunflower in the U.S.A. Caterpillars are best where tractors drive the combine as field speed should be under 2 m.p.h.

Where combine harvesting is practised the matter of suitable dryers, for final conditioning for storage of the seed, becomes of considerable importance.

In the diagram given of the Massey-Harris pick-up and header as used

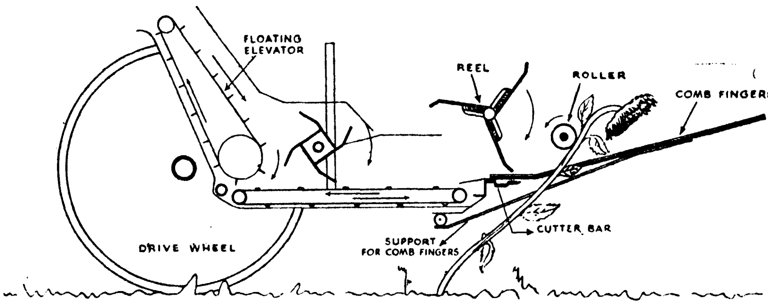


FIGURE 7

Diagram of Massey-Harris comb pick-up for harvesting sunflower. This shows how the plant is bent as the machine moves forward, until the stem just below the head strikes the cutter bar and is taken back by the reel to the conveyor.

for sunflower (see Figure 7) it will be seen how the plant is drawn down by the combs so that the head is bent and finally decapitated by the cutter bar, before passing on to the conveyor.

Combining of sunflower is also done in Australia, where the 'Sunshine' header combine is used and since this machine is now available in this country it may well prove very useful for the purpose. No trials here have so far been carried out but its simple construction, the fitting of a short and light comb as standard and the special device for the taking of the heads to the cutter bar, for which operation the close spacing of sunflower in rows does not appear to present any difficulty, seem to

render it likely to be a very useful tool for the job. The form of 'Sunshine' drum, as used in Australia, seems to be more suitable for combining, as far as the threshing operation is concerned, under our more variable conditions.

But, as most combine harvester manufacturers point out, successful threshing with a combine can only be accomplished if the plants are thoroughly dry—that is all foliage faded and the heads fairly hard and deep brown or even black, in other words much in the same state as beans to be threshed. It is for this reason, that the writer cannot foresee the possibility of 'combining' as a generally economical proposition in Britain. Our summers are far too short usually and the August-September weather too uncertain for crops, except in the very favoured areas, already mentioned, ever to reach this stage safely. Long before this state of ripeness is achieved, which would entail a moisture content of 16

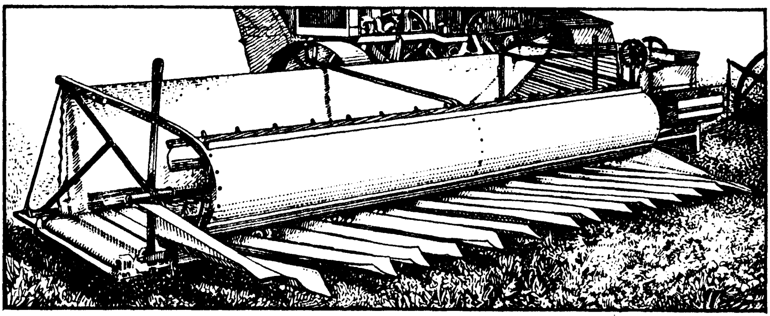


FIGURE 8

Argentine 'Sirio' Combine Harvester with fingers for sunflower, sails and conveyor band.

per cent or less, Botrytis would have set in, as it so frequently does now, often even before the kernels are filled and while the moisture content is still around 45 per cent. If Botrytis was avoided it is certain that in many cases the greenfinches would have robbed 50 per cent of the majority of the crops.

But there are other considerations when one is thinking in terms of almost total dryness of a standing sunflower crop. First we should have to make a re-selection of varieties and choose those that hold their seeds tight, even when the head is nearly dry and deep brown. Not all varieties will do this so that, with some, the risk of loss by shedding in a wind, or even under normal conditions, would be excessive. Even with the former

varieties we should still be up against the objection that the Argentinos have to 'combine-harvesting'—the great loss of seed shed through the touch of the 'combs' and 'sails'. For this latter reason the Argentine Ministry of Agriculture reports that in most cases combining is not desirable. Where for some reason the crop has been allowed to dry out to a state where the seed may shatter it is advantageous to combine very early in the day while the heads are wet with dew.

Taking the long view it seems that the answer, where mechanical harvesting is concerned, will be found in a machine, such as that mentioned in a previous paragraph, which will de-head and deliver into a trailer ready for threshing with a 'sheller', since the latter will de-seed the heads even if the moisture content is as high as 45 per cent. The 'combine' is of course still preferable where local conditions allow.

The following makes of combine harvesters are in use in the Argentine: Massey-Harris, Cosino y Caputo, F.A.M.A.

International Harvester and Allis Chalmers Combine machines are also in use in North America.

YIELDS

It has already been pointed out that yields so far obtained in this country on trials have proved to be very much higher than the average obtained elsewhere. While the average abroad for different countries ranges from 7 cwt. to 12 cwt. per acre we have obtained up to 30 cwt. and, in one case, considerably more. There seems no reason why we should not average one ton per acre with the varieties we are growing, under our spacings, once growers realize that sunflower needs a different technique to other crops for oil-kernel production. (See notes under 'Fertilizers', Chapter V.)

CHAPTER IX

SEED TREATMENT

KEEPING QUALITIES

Damp sunflower seed heats very readily. With a moisture content of over 20 per cent it will heat up within twelve hours or less. It is unsafe to store sunflower seed with a moisture content exceeding 11–12 per cent.[1] Therefore the question of drying the seed is of major importance. The rapid heating of freshly threshed seed from a moist crop, which may well attain a temperature of 110° F. within twelve to fifteen hours, is of course due largely to enzyme and bacterial action. Considerable investigation needs to be made into the species of bacteria found in sunflower as well as the enzymes, whether latent or produced by the bacteria, since this pre-heating, even when the seed is redried artificially, may have a very deleterious effect on the keeping qualities, the oil content and germination.

RIPENESS

At this juncture it may be as well to define clearly what we mean by ripeness. As has been pointed out in the previous chapter there are certain outward signs by which we can judge when the kernel has reached maturity, that is to say the stage when it will attain no greater weight and receive no further nutrients from the parent plant. This stage is commonly called 'ripeness' and for that reason is how it has been referred to in the previous chapter. But it is really rather maturity only and therefore but one stage of ripeness. During the maturing stages, from the time when the pollination has taken place, with the subsequent fertilization of the ovum, various processes are gone through. First the fertilized ovum gradually assumes the form of the embryo and the formation of endosperm tissue takes place in the embryo sac, while there is a gradual accumulation of proteins and carbohydrates in the endosperm tissue itself. While the kernel and fruit are ripening other changes are going on in the plant and there is a general movement from below upwards of water, as well as other materials, from the lower parts of the plants and

[1] Canadian evidence states 12 per cent in bulk, 14 per cent in sacks, but their climate is normally drier than that of Britain.

leaves, all of which are ultimately utilized in the formation of the embryo and its store of reserve foods.

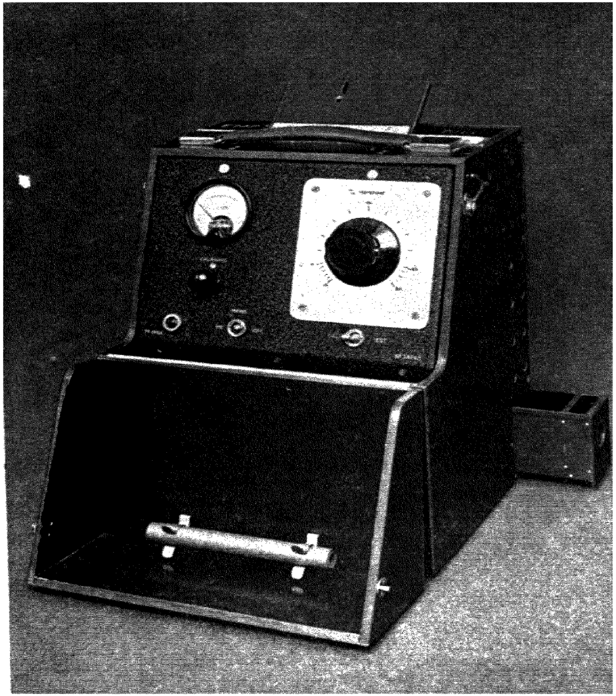
Plant death takes place from the roots up, starting before the kernel reaches ripeness, and the degrees of ripeness may be roughly divided into four stages: (1) milky ripe; (2) yellow ripe; (3) ripe; and (4) dead ripe.

In the first stage there is very considerable water in the endosperm tissue and it is frequently at this stage that sunflower has been harvested for one cause or another. If, however, the 'seeds' are left on the plant they will naturally reach the final or fourth stage, a state at which no artificial drying is necessary, though even in stage 3 the seeds are sufficiently dry for storage and this is probably the ideal stage at which to harvest, since there is no risk of shedding.

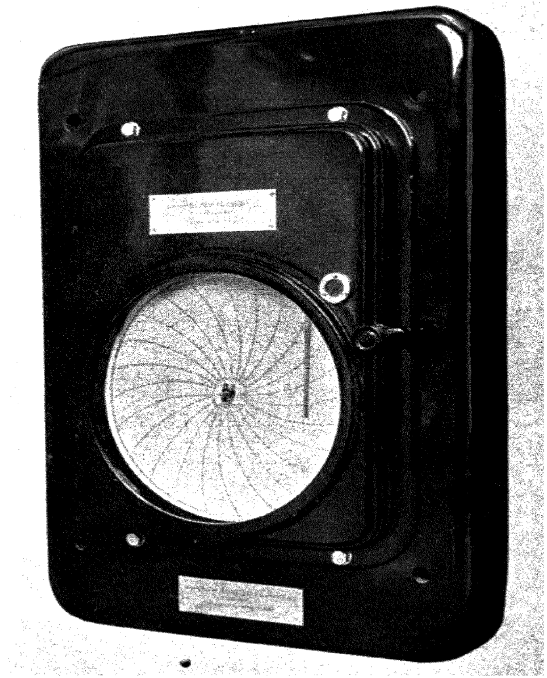
In considering the matter of artificial drying—necessary only when it is impossible to allow the seeds to attain the third stage mentioned above and generally undesirable under any other circumstances—it must be pointed out that what are generally referred to as the 'seeds' of the sunflower are not really seeds in the botanical sense but actually fruit. This type of fruit is common to the compositae but the fact that it is a fruit entails a different structure and on this difference much of the technique of drying depends. The husk or pericarp of these fruits consists of an epicarp or protective outer layer, a mesocarp, the thick middle layer, and an endocarp or inner layer.

'SEED' STRUCTURE

The diagram on page 113 shows the structure of the actual fruit. The outer epicarp coat, (*a*) which carries the pigment in most varieties, is extremely thin and slightly downy and serves to hold together the longitudinal sections of the cortex proper, and probably as a protection against bacterial and fungoid entry. The thick mesocarp (*b*), is built up, like plywood, of innumerable layers of hard fibrous material, with these layers laid lengthwise from the base to tip of the seed, their lines of cleavage running between the exterior of the seed and the interior. They are firmly bound at the base where the seed joined the flower head. A thin binding layer, the endocarp (*c*), completes the main husk structure. Within this is a wadding of layers of porous cellular material, of a silken appearance which, in the growing stage, is joined to and forms a bed and feeding surface for the kernel. This cellular material is capable of holding considerable amounts of moisture and is easily broken down by bacteria or fungi, thus forming a subsidiary source of infection and degradation of the kernel (*d*), which contains the embryo or germ.

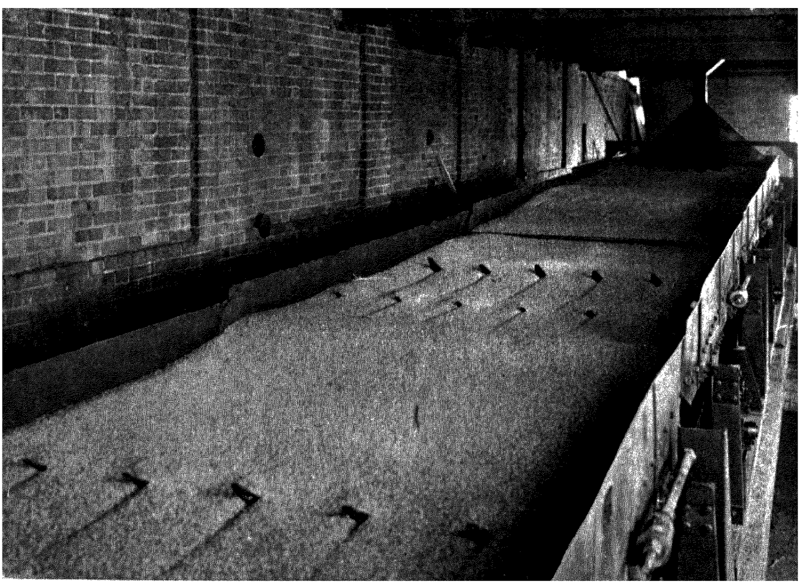


15 (*a*). Marconi Electric Moisture Meter Type TF819A



15 (*b*). Marconi Visual Moisture Recorder for distant control and continuous reading in connection with drying plant. Type TF818(OA148A)

16 (*a*). Ransomes-Davies Grain Dryer owned by Mr. J. G. Henson of Boothby Graffoe, Lincs. Taken from discharge end



16 (*b*). Four Stage Butterley Goodall Dryer showing shaker buffers at side and weirs and ploughs

Damage to the outer coat (*a*) by bacterial action, moulds or mechanical causes, removes the binding from the inner coat ply-structure, allowing the layers to open slightly and infection, particularly the hyphae of certain fungi, thereby to enter to the inner cellular bed and kernel. In the problem of drying, therefore, it seems that we should first avoid preheating which, by bacterial action or the reaction of enzymes, will destroy this protective outer coat, which in its natural state is supplied

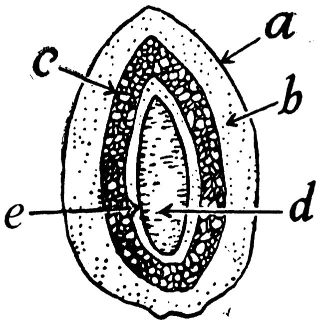


Fig. 1

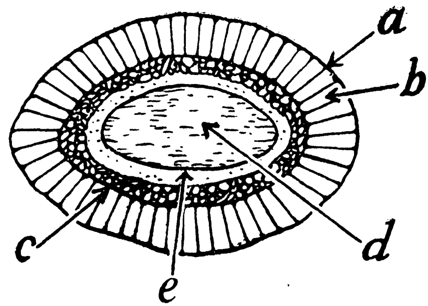


Fig. 2

FIGURE 9

Fig. 1 above shows a longitudinal section of the sunflower fruit: *a.* the very thin epicarp, frequently carrying colour; *b.* the hard mesocarp; *c.* the cellular endocarp; *d.* the kernel; *e.* testa. Fig. 2 shows a transverse section of the fruit showing the arrangement of the 'ply' layers of fibre forming the mesocarp. For actual photograph of the structure of the mesocarp, taken when, due to certain causes, the epicarp has been destroyed and disintegration has taken place, see Plate 17. Note. In the fully ripe state of the fruit there is considerable space between the seed and the pericarp, where moisture can be held in addition to that in the kernel itself. It is quite possible for the whole 'seed' to appear dry, with only 5 per cent to 8 per cent moisture in the husk, but as much as 18 per cent to 20 per cent retained internally. The kernel, *d.*, with its surrounding testa forms the seed.

with protective resins or waxes, and is to some extent elastic. In the actual drying process we must aim to copy natural sun and air drying as far as possible, by removing excess moisture from the inner lining cells, without either breaking the outer coat, destroying the flexibility and contact of the inner coat layers or drying out the kernel to an excessive degree. At the same time we must take steps to avoid the setting up of conditions for further bacterial action.

In some types of seeds particularly, lack of care in drying may easily cause the seed coat to split along the natural line of cleavage utilized by the embryo, at the second stage of germination, for the exit of the rootlet.

Avoidance of damage to the epicarp is obtained by allowing the fruit to attain the third stage of ripeness while on the plant, at which stage the epicarp itself is very considerably hardened and therefore less liable to mechanical damage, while the whole is in a state of dryness at which bacterial action is unlikely.

DRYING

Where seed has been dried down to 16 per cent in the field it should only be necessary to air dry it before bagging and storage, after, of course, careful cleaning to remove residues such as florets, petals and blind seed. In this case spread it thinly over a dry floor, with plenty of air circulation, turning at regular daily intervals till the moisture content goes down to 12 per cent or preferably slightly lower.[1]

With seed over 16 per cent in moisture artificial drying is essential and no delay should take place after threshing especially if the moisture content is at all high.

Moisture testing and control should be very carefully attended to (see notes later).

ARTIFICIAL DRYING—GENERAL

It is probably true to say that the evolution of a satisfactory machine for the artificial drying of all seeds, especially in the case of those required for germination, is in an intermediate stage; the vast majority of dryers are based on patents of the last century intended to provide processes for entirely different substances. While therefore the majority are suitable for inorganic substances and those with non-volatile components, they are of little use for living matter, particularly oil seeds, except under the most favourable conditions. It was not until the combine harvester was pressed into extensive use to meet the exigencies of war-time grain production on a large scale that the importance of artificial drying plant for farm crops was recognized as a necessity. Nor was it until an excessively wet season that the failure of the old designs was fully realized. The many factors involved in approaching the attainment of natural results by the simulation of natural means seems

[1] See Appendix I (1).

to have escaped the designer, because the conditions and areas of grain and seed production in the past had not really made their study necessary.

Apart, however, from the constructional side of dryer design, it had never been found necessary to consider anything but the mere removal of a certain amount of moisture nor was it generally realized that there were other factors, besides water, which might be affected by or have a bearing on the artificial drying process and its consequent results. As long as the seed was 'cooked' without being burnt, the manufacturers, as well as the majority of growers, were satisfied, though this did not necessarily apply to either the brewers, the maltsters or the millers. The latter at least realized that the degree of moisture in dried grain had some commercial significance, but even adequate control of moisture extraction meant little to most people. It is true that the miller wanted dry grain to which he could add moisture and the brewer wanted sufficient moisture to maintain a maximum and even germination in his barley. The farmer worried little, so long as the grain would either keep or sell, whether he lost 5 per cent or more of its weight by over extraction of water, and he seldom required artificially dried grain for reproduction.

But artificial drying to-day concerns not only seeds that are to be put to commercial manufacturing uses but also seed that is to be used for reproduction, and this side of the question, particularly in the post-war years, will be of the greatest importance, whether in grain or oil seeds or certain market-garden seeds and, more especially, in grass seeds. Here we are dealing with a living thing in which the maximum vitality must be maintained by providing not only the most suitable conditions for vitality but also the least suitable condition for attack by bacteria and other micro-organisms or the products of their activity.

In drying most seeds it has been the practice to step up the temperature gradually. In fact any sudden shock to the live germ may weaken or even kill it and there is of course a maximum temperature with each variety of seed beyond which one cannot go without causing injury. In any case high temperatures at an early stage, especially in the case of sunflower, on account of its thick husk and the oils and resins, etc., present, may only tend to seal the moisture within as in the case of a joint placed in a hot oven. Such sealing may not only make it difficult to withdraw inner moisture but may also provide ideal conditions for certain micro-organisms to work at a later stage.

In the case of oil seeds and again particularly sunflower, the consideration of these factors is of the utmost importance, since they not only affect the keeping qualities of the 'seed', if it is intended for crush-

ing at a later stage, but may also affect the actual oil content. Still more so are they of importance where subsequent maximum germination is desired.

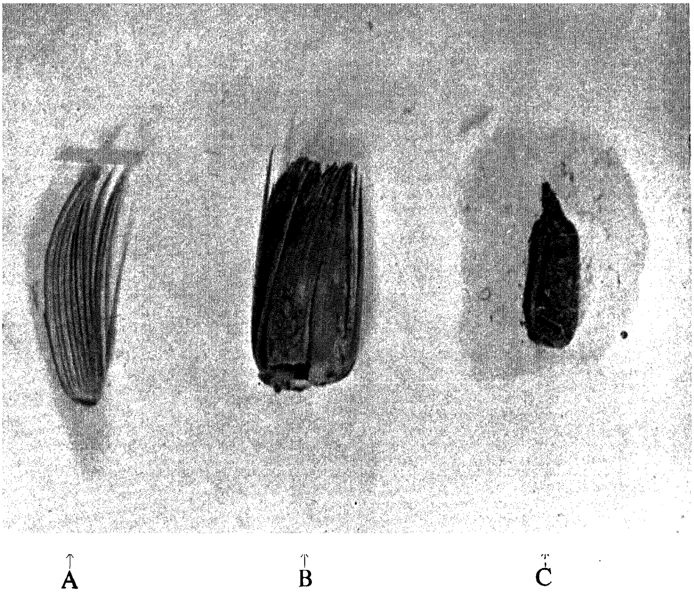
As has been shown above the structure of the 'seed' of the sunflower differs mechanically from that of most other farm seeds. The contents of the kernel are a mixture of oils some of which are volatile at considerably below 100° F., and others at 120° F. We have to consider what are the amino-acids in the natural undried seed, under different conditions, at time of artificial drying; what enzymes are involved and what chemical actions they produce; at what temperatures, under differing combinations of other factors, they are most active; at what temperatures their activity ceases or bacterial action is set up.

Vegetable oils in the kernel too are really emulsions of oil and water and therefore the application of heat needs a new technique if the excess water is to be withdrawn from the emulsion without volatilizing or altering the oil content. The oil, be it remembered, in sown 'seed', acts as a feeder for the embryo and the plant in the cotyledon stage. Dry heat does not readily remove water in emulsion and driers in the past have based their functions on dry heat. The proof of the above statement is to be found in blotting-paper which has had all its moisture removed by the heat of a fire and therefore fails to absorb ink. Too rapid drying of the 'seed' by the use of high temperatures and dry, hot air in the first stage, tends to make the husk an impervious coat against the extraction of much internal moisture. Also, under these conditions, the husk tends to absorb moisture slowly, while in storage, from the outer air while internal conditions are ripe for fermentation and decay. Moist hot air—steam—not only keeps the husk moist and pervious during the drying process but in itself will remove free water from the oil emulsion.

While therefore many existing drying plants form a ready method of merely drying sunflower seed for commercial use, they are far from satisfactory in their results, even for that purpose, while for reproduction they can and do usually become very detrimental to germination. With already naturally very dry seed, most so-called grain dryers will work, though they are not conditioners as they should be. In most cases it is only by several repetitions of the process that the seed can even be reduced to a moisture content at which it can safely be stored.

Since, in growing sunflower on a farm scale at market prices, artificial drying becomes essential, the above represent some of the problems we are faced with and the research that we must consider.

The manufacturer of dryers has therefore to combine with the biologist, the bacteriologist and the chemist and consider what effect period



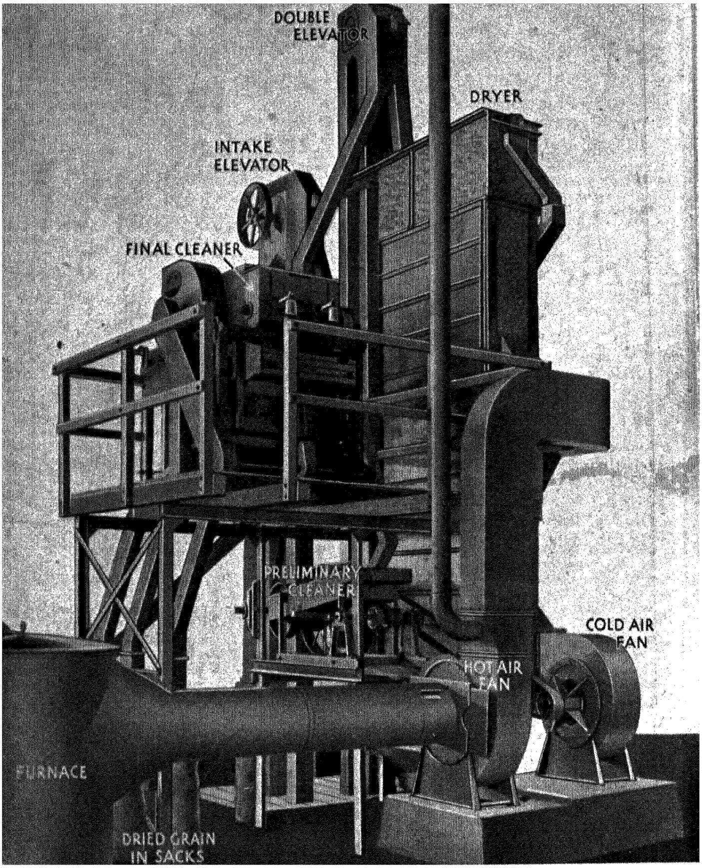
17. Degradation of Sunflower

(A) Enlarged photograph of section of sunflower husk showing build-up of layers of main cortex (mesocarp).

(B) Enlarged photograph of 'seed' disintegrating, due to destruction of pericarp by ensyme and bacterial action. Note break-up of mesocarp on lines as shown in (A).

(C) Kernel or true seed from (B) (enlarged) showing complete degradation, accompanied by discoloration, due to penetration of hyphae of fungi through the cortex, aided, probably, by bacterial attack.

Degradation as shown in (A) and (B) above is most commonly caused in seed which has heated, after threshing in a moist condition, before being artificially dried. It may also occur in seed which has been dried but stored with excess internal moisture, favouring microfungi later



18. Turner-Wellbourne Oxford Grain Dryer

of drying, temperatures, moisture and humidity control, in the case of *each* species of seed to be dried, have on the result.

BACTERIA AND ENZYMES

It appears that seed that has heated naturally to 110° F. shows later deterioration of the kernel either by the action of bacteria or enzymes acting as chemical reagents. It may therefore be supposed that this temperature is too high, at least if allowed lengthy play, and slower drying at a lower temperature may be necessary. Ideally the seed should not be allowed to heat but, if at all moist, should be dried without delay so as either to destroy or render dormant the bacteria and, at least, prevent their producing deleterious enzymes.

The extremely rapid way in which threshed seed, if at all moist or if mixed with moist vegetable matter, will heat, accompanied as the condition is by the smell of generated alcohols, points to the decomposition of the sugars by the action of bacteria of the B. Butyricus type or of other enzyme-producing organisms. Seed with a moisture content of 25 per cent upwards will, as has been mentioned, attain temperatures up to 110° F. within twelve hours, especially if placed in bags. The result of this action is even more strikingly demonstrated in the head refuse from a threshed crop. The formation of moulds rapidly follows such heating and it is one function of a dryer to destroy the spores of these moulds and such yeasts, which may penetrate into the seed, as well as to reduce the moisture content to a point at which conditions are unfavourable for their growth. If this is not done—and seed may appear dry to the feel and have a sound look, largely due to cleaning processes—kernel decay will show itself at a later period. The chief action by micro-organisms is anaerobic as shown by the avoidance of heating where seed is spaced thinly and air allowed to circulate by frequent turning, though this process, of course, also favours rapid loss of heat.

So far little or no work appears to have been done to determine what micro-organisms or enzymes are common to sunflower or how they work.

It may be worth while explaining here what the problem really entails. Fermentation in all matter, especially vegetable matter, living or dead, but particularly the latter, is due to the action of living organisms such as bacteria, yeasts and moulds or by enzymes, those chemical reagents which are either inherent or produced by the bacteria, etc.

The action of such organisms is controlled partly by temperature, partly by moisture and air and, of course, in accordance with the suit-

able food available for them. All the bacteria, yeasts and moulds have certain minimum and maximum temperatures which preclude their action. In the case of bacteria, while they can be killed by heat, they only become dormant below their minimum temperature. There is also an optimum temperature under which conditions they are most active. Both the temperature extremes and the optimum will vary with different species. At temperatures over 110° F. most actively growing bacteria are destroyed though spores will withstand a much higher temperature. It is when they cease to live that vegetable matter, heated by the action of their growth or multiplication, tends to cool off.

Although most living organisms require air there are certain bacteria, of the anaerobic type, which are able to live and flourish without it and whether aerobic or anaerobic types predominate in decaying vegetable matter depends on the conditions of aeration. Moisture all living organisms must have and most require at least 30 per cent, an important point to remember when considering the keeping qualities of seed, though lack of moisture may only cause certain bacteria to become dormant and may not affect the enzymes.

Bacteria must have food for growth and multiplication and that food must be of a suitable nature and in a suitable condition for the needs of each species, so that we find different species feeding on different matter or components of a given mass. In general bacteria feed with great readiness on proteid foods, largely found in many plants, including sunflower. The kernel of sunflower seed being largely proteid is a desirable food for bacteria where the latter have not been rendered dormant.

Sunflower does contain quantities of certain sugars and these are readily attacked by that other form of micro-organic life, the yeasts; certain forms of bacteria, particularly B. Butyricus and B. Lactis acidi, will also feed on them. The action of both bacteria and yeasts is accompanied by their multiplication or growth.

The enzymes or chemical ferments do not grow like the living organisms, since they are non-living chemical substances. These, however, are produced by living bodies and are often secreted by the bacteria. This is to say that the bacteria can produce changes in matter by indirect action, i.e. the action of the enzymes they have produced. While, by drying or other means, we can inhibit the action of enzymes, once produced, these are liable to become active again on addition of moisture even if the bacteria responsible for their production have been killed.

These enzymes are what are termed catalysts; that is to say they have a catalytic action, which increases the rate at which normal reactions

or changes between two substances take place; or they may even start such a change by their presence. A very small amount of such a catalyst can effect a transformation in a very large amount of reacting substance. Enzymes act on many substances such as sugars, fats and proteins, producing in turn glucose, lactic acid, higher fatty acids and alcohols.

How far the changes in sunflower seed, after primary heating by bacterial action, are carried on by enzymes or how far other organisms are responsible has yet to be shown. For this reason extensive investigation into the whole subject is highly desirable since, due to climatic conditions in Britain, most sunflower crops here must be threshed in a comparatively moist state, thus having ideal moisture content for enzyme or bacterial action. If we can ascertain what bacteria are present and can ascertain the maximum temperature required to destroy them or the minimum moisture at which they remain active, we shall have advanced a long way in the technique of drying and obtain a far more satisfactory result, both for the storage of seed or the maintenance of germination, than by what are otherwise largely haphazard methods. All this is of major importance where seed is required for resowing.

It has been recognized that in the process of natural ripening and drying off of plants much of the amino-acids disappear from the seed. It is these chemical agents which cause considerable trouble in the degradation of seed that is removed before it has reached that stage of natural dryness, when it would normally be shed, since the action of these agents is increased according to the excess moisture present.

Enzymes such as produce the amino-acids can be neutralized by formaldehyde treatment and the possibility is that the first stages of heating of *moist* seed in bulk is caused by these. As these acids may cause destruction of the outer seed coat, or epicarp, their presence is probably a predisposing cause of later degradation of the kernel and germination itself, either by their action or by the facilities they give for the entry of bacteria. It has been shown that treatment of moist seed in bulk with weak formaldehyde solution does retard the heating process. Such treatment destroys enzymes and kills bacteria, but the pericarp protects the true seed within from injury.

Temperature has a twofold action on the reaction of enzymes. Rise in temperature first speeds up their reaction and finally has a destructive effect upon the enzyme. There is no one optimum temperature for all conditions since the reaction depends on both the concentration of the enzyme, the concentration of the substance on which it is acting and the excess of moisture present at the time of action, as well as by the presence

of other substances. Optimum temperature may vary between 40° C. (104° F.) and 60° C. (140° F.).

Study of the above questions is therefore essential before we can satisfactorily tackle either the stage at which it is safe to take 'seed' from the plant, or before we can arrive at correct moisture control in the processes of drying, since without this study we shall not approximate to nature in the artificial drying of seed. Any other method is merely working blindfold and the further we differ from natural conditions the more likely we are to have trouble.

Natural drying comprises not only the question of these amino-acids but also the different factors of heat, air and moisture control in fixed proportions. Artificial drying has always been based on the assumption that heat will drive out moisture, and that reduction of moisture to a certain degree gives seed in a naturally dry state; this has been shown to be completely erroneous in a really wet season with all crops, when abnormal conditions prevail. It is therefore time, if artificial drying of any crop, particularly of oil seeds, where the seed is needed for resowing, is to be satisfactory under all seasonal conditions, that technique be studied afresh both from the point of view of all factors and carried out with machinery designed on up-to-date and less rule-of-thumb lines.

DRYERS

Of the types of artificial dryers used in this country for grain the 'tray' type is not suitable for sunflower unless the moisture content of the seed is down to about 16 per cent and with that low moisture content it is quite easy and more economical to air dry on an open floor. The majority of crops that will be harvested in Britain will show a water content of 25 per cent to 45 per cent and in such cases the seed will neither flow through the hopper to the feed nor will it fail to conglomerate in the dryer itself and, in the higher moisture ranges, will become a sticky mass which will have to be dug out. Also, on account of the resins which exude with the application of heat, the load in the tray dryer becomes impervious to the hot air current so that, while the outside of the mass dries, the inner portion is untouched by the heat. In such cases the seed has to be put through the dryer several times with the risk that the same seed, that was outside the first time, retains its former position, resulting in part of the seed being overdried and part underdried, which leads to trouble at some later date after bagging.

Dryers of the vertical, such as the Turner 'Wellbourne', or horizontal type, such as the Ransome, will dry sunflower satisfactorily if careful

attention is given to temperatures. But in each case some method of feeding, either by open conveyor from floor level to the Ransome or by belt to the Turner, other than the normal grain hopper, must be arranged since the sunflower seed will not flow on the slope or through the feed aperture as used for grain, and, unless very dry, will have to be hand fed.

The Turner dryer requires some three tons of seed to fill it, before heat can be maintained, and even then the lower portions of the seed columns, since heat rises, do not attain the maximum heat desired. It is, however, possible, as is shown later, to overcome this drawback. This dryer seems very economical on fuel.

The horizontal Ransome has some distinct drawbacks of design relating largely to the difficulties of cleaning the drying surface, where batches of seed must be kept separate for one or other reason. This difficulty arises primarily from the buckling of the perforated surface which prevents the ladder bars from exercising a satisfactory cleaning process of the drying surface, when in motion—as much as a hundredweight or more of seed being left behind. And the chain belts, as well as the ladder bars, both of which tend to hold or leave behind much seed, make cleaning a lengthy process entailing several hours' work, since the complete dismantling of the chains and bars is entailed. Additionally, with sunflower, the bars take over some seed and a lot of other material, depositing it below the dryer where, as a result, fires are not infrequent occurrences. It appears that a little progressive thought in design would result in an easy solution of these problems. While, from the makers' point of view, such a change of design might not appear worth while, when the sunflower crop is in its infancy, these same features apply to some extent to the drying of other grain.

Generally speaking the vertical dryer is better in these respects than the horizontal as it is free of lodging obstructions and, except in special circumstances, the seed does flow by gravity. With the horizontal type it is not possible to dry seed with a moisture content over 25 per cent at one operation, since the seed nearest the perforated tray dries out but releases its moisture into the upper layer, which then has a higher moisture content. Moving to the next stage, whether hot or cold, mixes the seed and the drying operation must therefore be repeated.

Since husked seed, as that of sunflower, cannot be tested for moisture, even approximately, by feel, it is essential that some form of moisture tester be used before bagging. The safe moisture content is 12 per cent or under. Apparently dry 'seed' will hold considerable water in the kernel, probably in most cases sealed in temporarily by the first heat

application. This will later appear, perhaps some weeks afterwards. It may then cause heating and external mildew or, if completely sealed in the husk will cause rotted kernels only apparent when the 'seed' is de-husked.

In certain types of vertical dryer, where it is necessary completely to fill the hopper before the desired temperature can be attained and where the lower part of the hopper in any case cannot attain the desired temperature at the commencement of the operation, one is up against two difficulties. First this lower layer will either not be dried at all—and this entails putting a large portion of the contents of the hopper through again in a semi-dried state to even up the parcel—or, secondly, if the seed is very moist and contains much extraneous matter, this lower layer frequently conglomerates and refuses to flow, thus entailing the very lengthy proceeding of dismantling portions of the dryer. At worst this lower layer may even heat spontaneously. In the case of vertical dryers, when drying moist seed of this nature, it is highly advisable to feed in first a quantity of other material, such as oat or wheat chaff, which will be winnowed out in the later cleaning process, in order to fill the lower part of the drying hopper, so that the lowest layer of sunflower is at a level where the heat is sufficiently high.

The use of chaff, as described above, is also one way of getting over the difficulty of drying quantities of seed which are insufficient to fill a vertical dryer, without which the necessary heat, again, cannot be attained.

While speaking of the cleaning of drying plant it should be strongly advised that all elevators should be replaced by open conveyors as far as possible and both these and all chutes be of flush-jointed, sheet metal. Sunflower seed, with any high moisture content, is so sticky that it will cling to corners and especially to wood and, if left for a day or two, will be very hard to remove, especially where, as is so frequently the case, small portions of head which can only be removed after drying are included with the threshed seed. Cleaning and winnowing machinery needs particular attention and in all cases must be cleaned thoroughly within an hour or two of use.

In a crop cut moist it has been found that, whereas the seed itself may only show 35 per cent of moisture, the percentage in the vegetable material may be as high as 80 per cent. Since in such a state perfect cleaning in threshing is impossible and since it is desirable to remove the heavily moisture-laden trash as soon as possible, to facilitate the drying process, a cleaning stage, consisting of a wide spread shaker screen, should be interposed at an early stage. The removal of this trash should reduce pre-drying moisture content to 18–25 per cent, and much labour

occasioned by clogging, especially in vertical type dryers, will be saved. If this trash, even in a dry crop, is allowed to remain longer than is absolutely unavoidable it will be found that it absorbs the moisture given off by the seed, particularly that in the lowest layer of the dryer, and tends to redistribute this moisture to the seed during the cooling stage besides, of course, slowing the whole drying process.

All dryers using perforated metal for the distribution of heat clog rapidly with sunflower dust and chaff, due to its sticky nature. This not only reduces the heating surface but causes a complete upset of heat and air control, since higher air velocity will be attained through the unclogged portions and only maximum heat will percolate there.

It seems that the most suitable dryer for sunflower is the Butterley-Goodall. Apart from its all metal construction and its complete absence of extraneous parts on the drying tables, it does by its construction and method of working provide even drying of all seed, and is very adaptable to heat and moisture control.

In the Butterley-Goodall dryer the seed passes over three or more trays, which can be run at different temperatures or alternated hot and cold at will, thus giving wide flexibility of temperature at one processing.

The construction of this latter dryer consists of trays with easily removable latitudinal overlapping plates of smooth metal, between the one-eighth of an inch overlaps of which the conditioned hot or cold air is blown every four or five inches of the surface. This blast in itself, being a strong one, moves the seed. But each tray has a jerk motion, which not only shakes the seed but moves the grains longitudinally down the tray to a sill. The sill is adjustable and therefore regulates depth of spread. The trays being inclined in the direction of travel, the seed is spilled over the sill down to the next tray, situated at a slightly lower level. On the spill the seed is again mixed and turned before receiving treatment on the next tray, and so on. When all the seed has passed over the machine, at most only a few pounds of seed remain against the sill of each tray and, the metal being smooth and with no projections, it is only necessary to brush the surplus off. Ploughs can be fitted to each tray to increase the turning motion as also can additional rotary fingers for further turning of the progressing seed.

The travel of each tray and the strength of jerk is controllable and this tends to regulate the speed of flow across the tray.

Since the main means of motion is by gravity there is no difficulty in introducing a cleaning stage between, say, the first and second stage, without recourse to elevators or conveyors.

The Butterley-Goodall dryer combines new principles and is largely

used by the brewing trade for the conditioning of barley as well as for the drying of that very difficult material, brewers' grains.

The method of conduction of hot air renders it simple to inject steam through the grain, under the same fan pressure, where such is desirable for water extraction from an emulsion, as found in oil seeds.

HOT-AIR DRYING

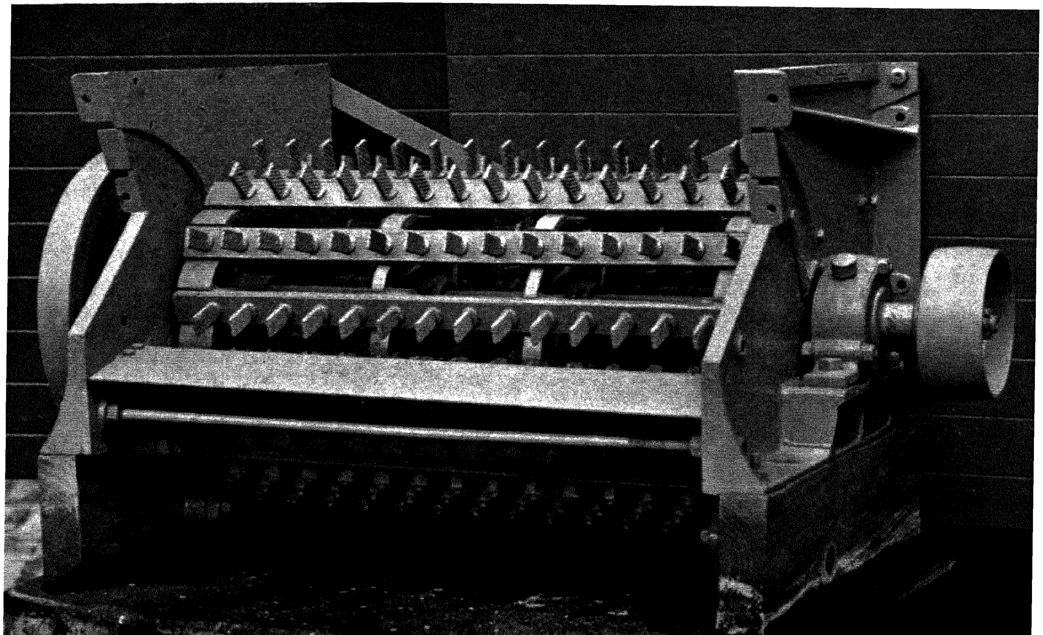
Although 130° F. is well below the temperature at which sunflower oil will melt and exude it is inadvisable to dry at temperatures exceeding 110° F. inlet air temperature (probably rather 106–108° F.), if the seed is intended for germination, and probably not over 115° F. where it is required for oil extraction. Certain of the volatile oils will, however, be dispersed at a temperature well below 100° F.

Certainly a slower process at the lower temperature is preferable to a higher temperature and a quicker passing across the dryer. Depth of seed or speed of feed across the dryer will have to be regulated according to moisture content and it is advisable to take constant moisture tests with some instantaneously recording instrument, such as the Marconi 'Moisture Meter'. At the final stage it is not necessary to ascertain the exact moisture content so that the calibration need only be such as to show that the moisture is not in excess of 12 per cent. (See 'Moisture Testing', below.)

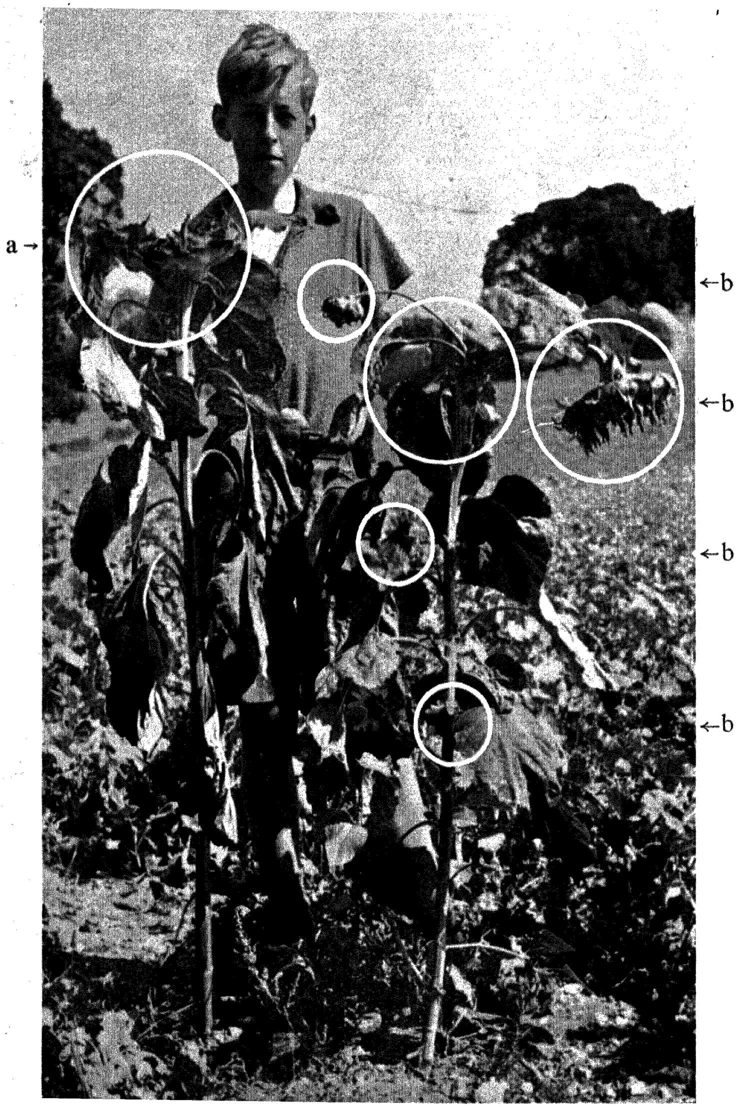
COST OF DRYING

It is impossible to arrive at any exact costing for the artificial drying of sunflower. Such costs must be based on each type of dryer used, as on their relative suitability for dealing with this particular crop largely depends the actual costing, in view of labour involved. Obviously where a particular type of dryer is not adapted to deal with this seed in the most economical way, the cost will be much higher and it is for this reason that suitable dryers should be used where possible and others modified accordingly.

In regard to other grains, artificially dried, scales of charges, based on relative moisture content, have been got out by the Farm Crop Driers' Association, but even these figures do not seem to be entirely satisfactory as they do not take into account the capital cost involved in the installation of different makes of dryers nor the varying labour involved in working them. In the case of sunflower, however, other more complicated problems are involved. Certain types of dryer, being less suitable



19. Ransomes Shredder (cover boards and hood removed). The revolving and stationary teeth are fluted and allowance is made for side adjustment of the stationary peg plates. Speed:—for dry matter, 1,400 r.p.m.; for wet sunflower heads, 1,000 r.p.m. Power, 5 h.p.
This machine could be usefully substituted for a cutter blower, if latter was not available, for the conversion of a sunflower crop, for silage



20. 'Rogues'. (a) Horizontal head—a bird table. (b) Multi-heads. Only the main head will ripen and the yield will be small

for this crop than others, involve greater labour and considerably longer time to achieve a given moisture reduction than others. Also the moisture range of undried sunflower seed is infinitely greater than that of grain crops and the whole problem is complicated by the very varying conditions of the threshed seed in regard to possible, and probable, content of extraneous vegetable waste, to be first dried and later removed. The latter event, particularly in so far as it impinges on ease of drying and the time factor, can undoubtedly be overcome to some extent by pre-cleaning and/or a preliminary drying plus cleaning stage.

STEAM DRYING—MOISTURE TESTING

It is highly inadvisable to attempt to test the dryness of sunflower seed by feel, especially shortly after drying artificially. It is probable that the seed will feel cold and dry, have a typical smooth touch and bright appearance, but there may well be moisture locked within, in excess of the safety percentage. Either such moisture will exude later and cause external mildew, and even heating or, being unable to escape, cause kernel decay. In fact such 'typically' dry seed, on test, has been found to contain as much as 8 per cent or more of excess moisture.

For this reason a ready and accurate method of testing for moisture is essential, not only after the drying process, thus allowing the seed to be further dried if necessary, but also during drying, in order to ascertain whether further treatment is necessary or not.[1] In the case of sale of seed by weight moisture testing, during drying, is equally important as it is by no means difficult to overdry thus not only losing weight but possibly interfering with germination.

The usual gravimetric process for testing has been to weigh a quantity of seed and reduce to ash, weighing the residue, when the difference will give the moisture content. But such a method is lengthy and laborious and, by the time it is completed, a large volume of seed may have passed over the dryer or the dryer may already be in use for another variety. The electrical method is instantaneous and for this purpose we have found the Marconi Moisture Meter most satisfactory. A test with this instrument, correctly calibrated for sunflower, can be taken in a matter of seconds and the readings will be accurate to within 0·5 per cent. While with this meter tests can be made before, during or after drying, it may be even more convenient, where a rapid flow of seed in process of drying is handled, to install a 'bleed-off', from the dryer feed or outlet, connected to a dial recording meter, by which means alteration of tem-

[1] See 'Bacteria and Enzymes', *supra.*

perature, depth of spread or alteration of flow rate may be promptly made as circumstances demand. This will eliminate the necessity of re-passing a large bulk of seed across the dryer.

ELECTRONIC MOISTURE MEASUREMENT

The theory of electronic measurement of moisture content, as used in the meter described above, is worth a short explanation.

It has long been known that a measurement of moisture content in materials below saturation point, that is the point at which the material can be described as containing free, unabsorbed water, can be made by observing the change in value of the dielectric properties of the substance.

In practice this means, if the material is not to be specially prepared, as in its application to seeds, that the indication used must be the dielectric[1] properties of a mixture consisting of the substance with air. In the simplest case the substance can be made to pack so closely that the content of air in the mixture is very small indeed, but where seeds, and especially large seeds, are involved, the proportion of air which is contained in the measuring chamber is very considerable.

Under such circumstances, and particularly when the moisture content of the seeds approaches saturation point, the measurement is complicated by the existence of apparently good electrical contact, due to the absorbed water, between portions of the seeds which are in contact with one another. The technique, therefore, of measuring dielectric properties is not a simple one, and the conditions of measurement must be determined both by the size of the particular variety of seed, the range of 'wet' values or readings required and the composition or structure of the seed itself. To make the latter point clearer it is obvious that a seed with a pronounced husk will behave in an entirely different fashion from one which is more or less homogeneous. Seeds containing a large proportion of oil will again behave differently owing to the dissimilarity in the disposition of the water they contain.

While the Marconi Moisture Meter has been designed to furnish the best possible compromise in the conditions of measurement, so that

[1] Dielectric—a medium admitting of passage of lines of force (by induction or electric discharge) of an electrostatic field thereby making it a seat of strain. Note: The measurement of dielectric properties at a fairly high frequency is carried out in the Meter with a special construction of electrode chamber and filling arrangements for the sample, to give the best statistical average of a number of tests.

seeds of different sizes and compositions can be dealt with, the calibration for a particular type of seed depends, amongst other things, on the amount of air contained in a fixed volume of the seed/air mixture and therefore must be different for seeds of varying natural sizes.

Calibration is therefore previously carried out by the makers by practical tests using a standard gravimetric method of comparison after a statistical analysis of the results and a graph chart is provided with the meter by which moisture percentage readings can be read-off against the dial figure for any type of seed. As far as the operator is concerned, therefore, such a meter is extremely simple, as no special skill is required and a number of accurate tests can be made in a few minutes.

Where a continual visual indication and a permanent record of moisture fluctuations is required a mains operated indicator and visual recorder, with the percentages traced on a radial 24-hour scale (similar to many temperature recorders) can be fitted within seventy-five feet of the sampling bleed-off.

The method of operating the Marconi Moisture Meter is as follows:

After connecting to the electric main or battery, switch on the current by depressing the lower switch. Now depress the upper switch and, when the needle on the left hand dial comes to rest, turn the knob on the right hand dial until the needle is centralized. Now switch off the upper switch and fill the measure provided with a level charge of seed. Empty this charge into the aperture at top of meter, making sure that all the seed descends below the slot into the measuring chamber, without attempting to press it down. Depress the switch at top again, when it will be found that the needle on the left hand dial is again decentralized. Recentralize the needle by means of the right hand dial knob. The figure on the right hand dial as shown by the pointer at top is now the moisture indicator. Compare this figure with the given calibration graph and the actual moisture content of the seed is at once read off. It is advisable to take a second test with the same seed in case it has not accurately packed the first time in the moisture chamber. To do this depress the knob on the right hand side of the meter which will allow the seed to empty into the drawer provided. Return the lever and withdraw the drawer emptying the seed into the upper chamber again. Recentralize the needle if necessary, with the upper switch still depressed, and read and check the figure on the right hand dial again.

Note. Since readings on the Marconi Moisture Meter depend largely on the 'packing' of a given quantity of seed in the chamber and since such 'packing' will vary with size and shape of seed it is essential that calibrations should be made for each variety of sunflower (though Pole

Star, Southern Cross and Mars, for example, are approximately identical in average size and shape and therefore for all practical purposes may be read off on the same graph), particularly in the case of varieties throwing seed considerably larger or smaller than the more standard varieties, otherwise a wide margin of error may result.

OIL CRUSHING

The extraction of oil from sunflower seed was the subject of one of the earliest English patents in the eighteenth century!

While small-scale crushing can be done by very primitive means, such as with the vat and 'follower' of a cheese press, large-scale crushing needs an efficient plant. Simple crushing is done by packing the seed into a coarse, strong cloth, placing same in a steel vat, and exerting pressure through a metal or wooden 'follower' under the press. This will extract a large percentage of the best oil. It will not however give the greatest extraction, though this can be increased with heat, and it will not leave a very good residue as the latter will contain much fibre in the way of husks.

The best feeding cake comes from decorticated seed and this is only obtainable by using a decorticator before crushing, so that what is actually crushed are the kernels only.

It having been suggested that this book would be incomplete without some more detailed description of the methods employed in the manufacture of oil and cake from sunflower seed in the revised edition, I quote the following notes from *Vegetable Fats and Oils* (Jamieson).[1] These are the outlines of the processes employed in U.S.A., such being similar to those for cottonseed and soybean.

Attention is first paid to the optimum moisture content (8–11 per cent) of the seed, which, if too dry, has its moisture content increased by blowing humid air through it and then all trash, sand, dust and metal is removed by successive screenings and a cyclone cleaner. When whole seed is crushed it is heated before placing in an hydraulic press; or, in the case of expeller mills, the seeds are crushed in a disc grinder and dried in rotary hot air or grain dryers to reduce the moisture content to 1 per cent before pressing in the newer types of expellers.

Centrifugal or other forms of decorticator are used to remove the hulls where decorticated seed is to be pressed, this being the more usual method since absence of hulls in the residue after extraction makes for a better cake with a minimum of fibre.

[1] Pages 200-6, the process being similar to that for cottonseed oil.

EXPELLER MILLS

The separated kernels are first ground to a coarse meal, dried by a rotary grain dryer and transferred to the steam-heated temperer where just sufficient water is added to give a satisfactory cake when the meal is pressed. The water adding device distributes water evenly throughout the meal, which is agitated by the temperer. The moisture content being about 2 per cent or less, the meal is fed into the expeller. The expressed oil is filtered by means of a filter press, and transferred to the storage tanks. Such oil is usually designated 'cold pressed' although in practice, due to the friction of the seed in the barrel of the expeller, both oil and cake are discharged hot. But the term differentiates it from the hot-pressed hydraulic oil for manufacturing purposes since expeller oil requires somewhat different treatment in the refining with caustic soda.

HYDRAULIC MILLS

While in Europe such mills are frequently used for pressing undecorticated seed, in the U.S.A. they press only decorticated seed. The U.S.A. presses are mostly of the steel box frame type, though a few are cage type. The separated kernels are passed through oil seed rolls and delivered over the 'cooker'. Cooking of the meal is one of the most important operations in the expression of oil by the hot process and considerable judgment is required in the process to get the maximum yield of best grade. The 'cooking' takes place at 215° to 220° F. The cooked meal is filled into the open cake formers, lined with a strip of press cloth; the two ends of the latter are turned over on the charge and a preliminary pressure exerted to compact the mass. The cake is now removed with a steel spatula, in its cloth, and placed in the lowest frame of the press, all frames being filled in succession. Compressed air is now turned on and the ram forces the frames upwards, each against the one above. The oil squeezed through the cloths flows over the sides into the gallery around the bottom frame and out through the trough into the settling tank. Pressure used may vary from 3,000 to 4,000 lb. per square inch, or more. The cakes removed from the presses have the cloths removed by a stripper and the soft ends of each cake are cut off by the trimmer and returned for repressing. The cakes themselves are sold entire or broken and mealed.

OIL TREATMENT

The oil run off into the settling tanks remains there until the press foots have settled when the clarified oil is drawn off into clean storage tanks. Most mills filter the oil as soon as expelled.

In Europe it is customary first to press cold and follow this by a hot pressing. The cold pressed oil is usually pale yellow, with a mild taste and pleasant flavour and is that used for salad and cooking oil and the making of butter substitutes. The hot pressed oil has a reddish-yellow colour and is chiefly used for technical purposes but by modern methods this can be refined for edible purposes by the caustic soda process, bleaching and deodorizing. Tests are made to determine the concentration of sodium hydroxide in water required for the quantity of free fatty acids in the sample. The oil is warmed by the coils in a refining kettle and the correct amount of soda lye added. After complete mixture, by agitation, the mixture is heated by the steam coils to temperatures around 120° F. at which stage the soap stock (refining foots) separate from the oil in clots. When the soap stock is in condition for settling the steam heat is shut off and the agitator stopped. Agitation should be gentle or much oil may be lost in the soap clots by emulsion. The oil is allowed to stand in the kettle until the soap stock has settled and become firm when the supernatant oil is slowly drawn off by gravity. If necessary the oil is washed with water, to remove the last of the soap stock, and dried. When the price of oil is sufficiently high to warrant a further process the soap stock is dissolved in water and centrifuged for the recovery of any remaining oil. Increasing use is being made of the continuous refining process, using a high-speed mixing chamber and centrifuging the oil and soap stock. This is stated to give a refining loss of about one-third less oil than by the batch-refining process.

Decortication is advisable in all cases as, apart from the greater desirability of the residue feeding cake, it has been found that if the crushing is done with undecorticated seeds, the husks reabsorb about 5 per cent of the extracted oil.

Sunflower is one of the most tricky oil seeds for the crusher on account of the wide variation found in husk-kernel percentage, due either to variety or growing conditions. This percentage varies as from 40 per cent to 60 per cent of husk.

Experiments at the University of Saskatchewan, 1945, show that seed with a low moisture content can be dehusked in a huller of the centrifugal impact type. It was found possible to attain 90 per cent hulling with only 10 per cent kernel breakage.

In Canada, however, the husks, on account of their protein and oil content, are permitted to be used, when ground, as fillers for feeding stuffs, and, with suitable bonding, provide excellent road surfacing material.

In Russia and Poland, where considerable sunflower oil extraction has been practised—one mill in Gdynia alone treating some 5,000 tons of sunflower seed annually before 1940—the husks were always used as fuel for the plant, both for power and heating, and a mill, in full production, needed no other fuel.

STORAGE OF OILS

The following notes are taken from *Food Technology*, Prescott and Proctor (McGraw-Hill Book Co., Inc., New York, 1937).

'The deterioration of oils in storage causes considerable loss not only in the raw materials but also in the food products in which they may be incorporated. Oils, like fats, are glycerol esters of fatty acids, but differ somewhat from the glycerides that they contain and in the amounts and proportions of each.

'Under certain conditions of storage flavours of oils change to a marked degree, certain of these changes, with the development of undesirable compounds, being characterized by rancidity. There is, however, much discussion among investigators regarding the exact compounds which cause the undesirable odours and tastes. It is believed that the chemical changes are largely oxidative and that these take place in oils and fats which contain unsaturated fatty esters, such changes giving rise to peroxides and other products with subsequent rise in acidity. As these reactions are primarily oxidations, the presence of oxygen is conducive to their development while the presence of moisture and high temperature accelerate the changes. Ultra violet light in particular has a marked ability to hasten such changes. Certain metals are very active catalysts in the oxidation of fats. Copper is most active, being able to reduce the induction period to less than one-tenth of its original value when present in only a fraction of a part per million. Iron, nickel and cobalt exhibit similar but less marked effects.

'Micro-organisms may bring about deteriorative changes in fats, both oxidative and hydrolytic.'

The conclusion to the notes is as follows: 'The above facts concerning deterioration of oils in storage lead to the conclusion that such products should be made from the freshest materials possible and should be brought to the highest degree of purity before storage. They should be

stored in suitable containers, preferably free from injurious metals, and protected as much as possible from access to oxygen, light and high temperatures. Moisture and impurities such as proteins in oils may serve as food for micro-organisms which in turn may produce enzymes also capable of bringing about changes. Since oils and fats are as a rule relatively free from moisture and impurities, micro-organisms play but a small part in such changes if the oil is carefully prepared and properly stored.'

CHAPTER X

DISPOSAL OF RESIDUES

STALKS

The stalks from which the heads have been removed, since they contain a large proportion of the lime and phosphates and are particularly rich in potash, taken from the soil, may be composted. But it might be more economical to throw these stalks into the cattle yards, to be broken up by treading and to be soaked in dung and urine before adding to the compost heap. This method in any case will not only make better use of urine but also make the stalks more easily used on the land in any way, since they will tend to break down. Whichever of the above methods is followed the stalks should be well disked into the land from which they came.

Where stalks are left standing on the field and it is not desired to remove them it will be best to run a heavy roller over them first when, by means of cross disking with sharp heavy disks, well loaded, they may be cut into small lengths, easily incorporated with the soil and they will thus rapidly break down. (See 'Analyses of Stalk', Chapter XII.)

Another method of stalk disposal is to rake the stalks into wind-rows, plough trenches, into which the stalks are laid, and cover up, leaving them to rot.

In Russia and many countries the stalks are allowed to dry and then burnt, the resultant ash, rich in potash and phosphates, being returned to the land. In this case it would be advisable to collect the ash and store in a dry place, not returning it until spring as otherwise the potash would be dissolved in winter and washed into the subsoil.

HEADS

Where the deseeded heads have a high moisture content they may be silaged, with or without molasses. But it is essential that they are placed into an airtight silo or butyric acid formation will take place instead of the desired lactic acid fermentation. Such silage is equal to that made from most root crops.

Here it might be noted that lactic acid is produced from the sugars by three groups of bacteria. The first of these, B. lactis acidi, is anaerobic which, since it produces the required optimum result in silage, is the reason why silos should be completely airtight. The second group,

B. acidi lactici, is aerobic and produces, in addition to lactic acid, ethyl alcohol and acetic acid. Thirdly, B. lactis aerogenes not only produces lactic acid but also ethyl alcohol, acetic acid and carbon dioxide, and hydrogen and methane. The presence of acetic acid produces 'sour' silage.

Otherwise these heads may also be added to the compost heap where they will rapidly ferment and break down.

Very dry heads may also be composted. Commercially, however, the latter make a good feeding meal, with considerable protein and about 6 per cent oil. Such meal has been produced for cattle and poultry for some years in Rhodesia. It is essential that the heads be shredded first, then well dried, preferably in a grass dryer, before being put through a hammer mill to reduce them to the required fine meal. (See 'Analyses', Chapter XII.)

Purchasers of sunflower 'meal' (as opposed to sunflower kernel meal, made from the oil seed cake, after oil extraction) should pay attention to what they buy. Such meal made from the heads and florets is a good feed meal (see 'Analyses') but the meal made from dryer and cleaner waste, containing as it does much blind seed and seed husk, has a very much lower feeding value and a very high indigestible fibre content. The latter is probably only of use as a bulk food for poultry, after preliminary scalding.

CELLULOSE

The stalks, as well as the heads, are rich in cellulose. It is possible that a means may be found to extract this for commercial use. In fact, in 1944, a factory for the extraction of cellulose from sunflower stalks was first erected in Hungary. As with the expansion of this crop in Britain very considerable quantities of stalks will be available, this matter is worth considerable investigation.[1]

POTASH

It was estimated that one acre of sunflower in Russia yielded 4,000 lb. of dry stalks giving 53 lb. of potash. The high potash content of the stalks (see 'Analyses') seems to be due to a proclivity on the part of sunflower to extract latent potash, unobtainable by most crops, from the lower soil levels. The return of sunflower stalks to the near surface soil, as ash, thus renders potash, obtained from the soil itself, though from far below the surface, available to following crops.

[1] See also Appendix I (3).

PART III

CHAPTER XI

SUNFLOWER CULTIVATION ABROAD

RUSSIA

Russia was the first country to cultivate sunflower on a very large scale and is still, to-day, the largest producer in the world. It has always been considered as a major crop, not only for its oil but also for its edible qualities, being eaten by all alike, in much the same way as are peanuts in America.

The Russian sunflower-growing districts are very widespread, particularly across central Russia, in Saratov, Samara, Kazan, Simbirsk, the Ukraine and Caucasus, and all the warmer parts of that vast country.

The sunflower has been the major source of vegetable oil for all purposes, particularly for cooking and canning.

No recent figures of production are available but in 1937 the crop was estimated at 6,000,000 tons. This is believed to have greatly increased.

U.S.A.

Sunflower was introduced into the U.S.A. in 1893 through the American Consul-General at St. Petersburg. This followed the U.S. Consular Report of February 1892 (No. 137, pp. 234–6). Within a very short time reports were coming in from several parts of the country as to the success of this crop and the use of the seed for making cake, particularly for the production of meat, milk, mutton, etc. Within a space of three years Oregon formally reported yields of 1,500 to 2,500 lb. of seed per acre, from a sowing of 10 lb. to the acre. It was also favourably reported on for the feed of horses and other stock, including pigs, although it is inclined to produce a rather soft fat in the latter, and the grain was used for poultry.

Since then sunflower has become a staple crop in many parts of the U.S.A., particularly in Kansas, Missouri and California. The kernels, too, are packeted and sold like peanuts.

Previous to 1939 the U.S.A. had been a large importer of vegetable oils and some steps had been taken in the production of groundnut in

the southern States as well. The impact of the war, however, impressed the U.S.A., with her shortage in home-produced cooking fats and although sunflower oil was used there to a large extent for vegetable lards, it became necessary, at a very early stage, to import further supplies from the Argentine. The following report from *Science* for March 1943 will show to what extent this was done:

'Sunflower seed oil, which may be obtained in large quantities from certain varieties of the common sunflower, is a possibility in the United States to help fill the shortage in edible oils due to war conditions.

'American sunflower grow luxuriantly in much of the country. Much of the seed finds its way into commerce but largely as bird and poultry feed. Missouri raises the largest commercial crop, even exceeding Kansas where the sunflower is the State flower. California is also raising the seed for market.

'Oil from sunflower seed was produced commercially in the United States a generation or so ago on a relatively small scale. The industry was discontinued because of the high labour costs when compared to labour costs in the other countries producing edible oils.

'Dr. G. S. Jamieson, of the U.S. Department of Agriculture, states that land suitable for corn is suitable for sunflowers. The crop can be planted and cultivated with the same implements. New mechanized methods of harvesting, threshing and processing will make it a profitable crop for oil as well as for poultry feed. Argentina is showing us the way this can be done. It is now producing large quantities of sunflower-seed oil and shipping much of it to the United States. In 1932 it produced only about 5,000 tons. The Spanish War cut off Argentina's supply of olive oil, and it started to raise its own table oils from peanuts, cottonseed, rape seed, and sunflower seed. Now the amount made from the sunflower far exceeds that from all other sources together. According to the U.S. Department of Commerce, it is nearly 500,000 tons a year, one-fourth of which is being sent to this country.'

Meanwhile the U.S.A. was stepping up its own production of sunflower and this process has been a cumulative one, as it was foreseen there how much more acute would be the world shortage of vegetable oils after the war. Official figures available show that the production in 1939 was 2,930,000 lb.; in 1940, 4,600,000 lb. of seed. But due partly to her own increasing needs and partly to political reasons, the Argentine ceased exports to the U.S.A. before the harvesting of the 1943 crop, in the late spring of that year. This gave a fresh impetus to U.S.A. production of both sunflower and groundnut as it was evident that even during the war she could not be dependent on outside sources. In 1945

the production was stated to be 6,000,000 lb. of seed, utilized for table oils and animal feeding stuffs.

ARGENTINE

The Argentine to-day is the second largest grower of sunflower.

For how long sunflower has been an important crop there it is hard to say, but it goes back at least to 1870.

Argentine was, however, always a large importer of olive oil from Spain. It was the cutting off of this source of oil supply which caused the Argentine to step up her sunflower acreage. In 1941 the production of sunflower oil was 99,180 tons, of which 60 per cent was exported, a large portion to the U.S.A. and Canada. This represented 633,480 tons of seed. The 1943 crop, harvested early in 1944, yielded over 1,000,000 tons of seed and those of 1944–5 and 1945–6 also passed the million ton mark.

Oil content of seed in Argentina is up to 45 per cent in the kernel and 29 per cent in the whole dry seed (8·6 per cent moisture). Average yield of seed per acre under 10 cwt.; maximum 15 cwt.

CANADA

Canada only started growing sunflower on any large scale since 1939, though previously it had been grown in some parts and considerable experimentation on the crop had gone on. Some of this research and experimental work, to be found in the official bulletins and reports, is of extraordinary interest.

In Canada, as in Britain, it was found early in the World War that only semi-dwarf varieties were suitable to the climate, the taller varieties being only suitable for forage or ensilage on account of their slower growth. The varieties now most favoured are Sunrise and Mennonite. Both these have been grown in Britain. The former seems to promise well but Mennonite is very dwarf, with a large head, and tends to grow top-heavy and fall over.

The 1943 crop was expected to yield an average of 700 lb. per acre from a total acreage of 30,000 acres. This is a comparatively low yield which seems due largely to the wide spacing adopted for the crop in Canada. Also the varieties grown chiefly over there, Mennonite (also largely grown in California) and Sunrise, from our own trials here, seem to be lower yielders than those we have selected. With a three-foot inter-plant spacing, only 6 lb. of seed are sown per acre.

The Canadian figures for oil content of their best variety are: whole

seed 24–25 per cent; kernel 50–55 per cent which, however, is 10 per cent higher than the Argentine. These figures do not, of course, represent commercial extraction rate. The Argentine extraction varies between 25 and 30 per cent and in Britain something slightly over 28 per cent is anticipated with varieties as grown at present.

The following advisory note appeared in the *Saskatchewan Farmer* for 15th February 1944: 'Summer fallow would probably have more moisture in it than land which produced a crop of grain in 1943. Since sunflowers are a cultivated crop to be grown in rows, I think it is most economical to put them in spring ploughed stubble.'

From the same journal the following note on 'Increasing Sunflower Production' is taken: 'Until recently production of sunflower in Canada was restricted chiefly to its use for ensilage in areas not suited to the production of corn, and to a lesser extent in the garden, where it served to provide seeds which were eaten much as peanuts are. Interest in the sunflower as a grain crop came about largely because of the shortage of edible vegetable oils in Canada soon after the outbreak of the present war. Twenty million pounds of sunflower oil were imported from the Argentine in 1942. The two outstanding varieties are Sunrise and Mennonite. Approximately 30,000 acres of these varieties were grown for grain in the prairie provinces in 1943. It is estimated that this crop will yield over 18½ million lb. of seed. It is capable of providing 4½ million pounds of high quality edible oil and more than 2,250 tons of excellent high protein oil meal suitable for stock feed. In addition there will be an abundance of seed available to meet the 50,000 acre objective set for 1944.'

The Canadian Bureau of Statistics reported in January 1944 that nearly 20,000,000 lb. of sunflower and rape seed had been harvested which would 'result in the production of vegetable oils to take the place of normal pre-war supplies'.

The *Financial Times of Canada* (Montreal, 19th May 1944), stated: 'Canada is still in urgent need of vegetable oils, and, while efforts are being made in the Dominion to increase the production of soybeans, sunflower and rape seed, as vital sources of oil, it is not possible to grow enough of them.'

A new vegetable oil plant,[1] costing over £500,000, was completed in Toronto in 1944, for the production of vegetable oils from sunflower, etc.

In 1945 Canadian Department of Agriculture announced the success of trials with a new variety, named Advance, capable of producing 49 per cent more oil than Mennonite, formerly so widely grown.

[1] See also p. 19.

In January 1946 the Dominion-Provincial Agricultural Conference laid down a plan for the growing of 28,000 acres, double the 1945 crop, by Western farmers as 'a major step towards ensuring their lack of shortenings (cooking fats)' and stated that 'a fine edible meal for that purpose would be extracted, on the decree of the Dominion Department of Agriculture, with a 47 per cent protein content'. Corporation Vegetable Oils, Ltd., of Altona, Man., have storage space for 50,000 bushels of sunflower seed and plant capable of producing 12,000 lb. of oil daily. The Eastern provinces also grow sunflower on a smaller scale.

URUGUAY

Uruguay is a large producer of vegetable oil crops, chiefly groundnut and sunflower. While the 1944 acreage of groundnut sown was some 30 per cent under that of 1943, the sunflower acreage was almost doubled, totalling about 133,685 acres. The 1944 crop was estimated to produce some 38,280 tons or nearly eight times the 1943 sunflower seed yield.

QUEENSLAND

The Queensland Department of Agriculture reports (1945) that there is widespread interest in sunflower as a staple crop with ceiling prices fixed at £32 per ton for graded seed. Sowing starts as soon as fear of frost is over and continues into January, midsummer being considered the optimum sowing period. 4 to 5 lb. per acre are sown but for combine harvesting 8–10 lb. is recommended, to reduce height of growth, and a heavier rate if required for ensilage. Yields average 1,000 lb. per acre with a 1,500 lb. maximum.

RHODESIA

No actual figures of production are available for Rhodesia but sunflower is a staple industry of considerable importance. Much experimentation is maintained both at the Bulawayo and Salisbury Agricultural Stations.

NIGERIA

No figures of production available. Seed submitted to Imperial Institute in 1945 showed only 22 to 24 per cent oil.

SUNFLOWER CULTIVATION ABROAD

CENTRAL EUROPE

Very considerable areas have been grown, for a very long period in Hungary, Bulgaria, Jugoslavia, Czechoslovakia, Bavaria and Roumania; and it is believed that Germany forced this production up in her satellite countries during the war.

Until 1944 Roumania held second place as the world's largest producer of sunflower seed and oil, next to Russia. This position has now been relinquished to Argentina.

While sunflower was always grown individually by the Polish peasantry, it was not until about 1935 that it became a sponsored crop on an extensive national scale.

CHILE

Sunflower seed 1944–5 crop was 28,050 metric tons, an increase of 55 per cent over the previous year, but its vegetable oil requirements are not met and importations, chiefly sunflower, are extensively depended on.

ALGERIA

Sunflower was scheduled as an alternative crop to castor bean, flax seed, cotton seed and soya bean under an order made in 1944, by which oil-seed bearing crops have been made compulsory.

OTHER GROWING COUNTRIES

Sunflower is grown in many other countries, such as Nyasaland, Cuba, Costa Rica, China, Kenya, France, Egypt, India, and its cultivation is spreading rapidly as the value of its oil and the adaptability of the crop is more and more realized, and the inevitable future shortage of edible oils everywhere.

The U.S. Bureau of Commerce, Washington, stated (Sept. 1946) that the world output of fats and oils may not reach pre-war level for three years or more. Also that estimated supplies for 1946 are nearly 4,000,000 tons short of pre-war average, while the world's import requirements are about double the available export supply.

CHAPTER XII

ANALYSES

It must be understood that while the following figures are taken from official publications, reports from scientific research stations, etc., they can only be considered as averages, since analyses will vary with the variety of seed, soil, climatic conditions, etc. In fact the variation between the figures obtained from different countries illustrates this. At the same time these figures will prove useful as comparative data regarding the components of the respective parts of the plant, the value for various feeding purposes and the needs of the plant itself, according to the purpose for which it is cultivated.

RESIDUE FOR MANURE

(Stalks, leaves, deseeded heads)	*Rhodesia*	*U.S.A.*
Phosphoric oxide		·98
Potash		28·90
Lime		12·00

DESEEDED HEADS

Water	11·73	7·40
Fat (ether extr.)	3·18	5·07
Protein	8·86	9·91
Carbohydrates	46·42	39·79
Crude fibre	18·19	18·44
Ash	11·62	19·39

LEAVES AND DESEEDED HEADS

(Air Dried for FODDER)		
Water	14·87	7·40
Fat (ether extr.)	2·82	4·09
Protein	16·50	10·15
Carbohydrates	42·15	38·83
Crude fibre	7·37	13·16
Ash	15·79	21·26

Note: The higher fat, fibre and ash in the U.S. figures is probably due to method of threshing leaving a higher proportion of seed in head.

SEED, KERNELS ONLY

	Argentine
Water	7·90
Oil	46·24
Proteins	29·41
Carbohydrates	7·50
Cellulose	4·80
Ash	4·15

SEED, HUSKS ONLY

	Argentine
Water	43·32
Oil	0·21
Proteins	4·21
Carbohydrates	30·94
Cellulose	52·41
Ash	1·78

SEED—WHOLE

Proportion of kernel to husk—Argentine figure: kernel 56·68; Husk 43·32.

Note: This figure has a wide range. It will vary (1) with variety, as even among the large seeded giants the proportion of kernel to husk varies, some having a large husk with a comparatively small kernel. It also varies (2) within a variety according to method of cultivation. Excess of inorganic fertilizer will increase the husk and decrease the kernel. Generally, however, the larger the seed the greater the proportion of husk. In the small seeded varieties the kernel tends to fill the husk, the opposite being the case with the larger seeded types.

	Great Britain	*Rhodesia*	*U.S.A.*	*Costa Rica*
Water	8·00	6·9	12·8	
Protein (Total)[1]	15·19	18·5	15·8	
Oil (Total)	32·39	21·5	20·52	28·30
Carbohydrate (Total)	23·9			
Carbohydrate (Digest.)	23·1	23·1		
Fibre	28·5		29·31	
Ash	3·0		3·00	

[1] Protein figures, as shown in the Ministry of Agriculture's *Journal* 1946, for British grown crops are 15 per cent with a maximum of 19 per cent.

SUNFLOWER CAKE (Decorticated)

	Argentine	*Gt. Britain*	*Kling's*
Water	10·00	15·80	9·60
Protein (Total)	34·00 to 37·00	32·80	37·40
Protein (Digest.)		27·90	
Oil (Total)	8·00 to 12·00	9·10	13·80
Oil (Digest.)		8·10	
Carbohydrate (Total)	22·00 to 26·00	27·10	22·50
Carbohydrate (Digest.)		25·10	20·40
Fibre		13·50	
Ash	8·00 to 10·00	1·60	6·70

Note: Analysis of cake will depend on method and degree of oil extraction.

Smetham's analysis[1] of Sunflower Cake (decorticated):

	per cent
Moisture	7·75
Oil	10·03
Albuminoids	37·00
Carbohydrates	21·14
Fibre	16·53
Ash	7·55

SUNFLOWER LEAVES

	Rhodesian (as taken)	*Rhodesian (air dried)*	*American (air dried)*
Water	78·76	14·87	12·51
Fat (ether extr.)	0·70	2·82	4·09
Protein	4·12	16·50	10·15
Carbohydrates	10·53	42·15	38·83
Crude fibre	1·97	7·87	13·16
Ash	3·95	15·79	21·26

[1] *Analyst*, 1910; 35, 59.

KERNEL MEAL (CULINARY) (*Canada, U.S.A:*)

Protein	47 per cent
Vitamin	'B'

SUNFLOWER HEAD MEAL

(From deseeded heads with 5–10 per cent seeds)

	Great Britain	*Rhodesia*	*Comparative figures for Wheat Bran*
Water	15·04	14·00	13·20
Protein	8·92	8·84	14·30
Oil (ether extr.)	3·31	5·86	4·20
Carbohydrates	46·98	29·70	52·20
Fibre	18·49	31·70	10·20
Ash	7.26	9·90	5·90

Albuminoid ratios: Sunflower 1 : 8·5, Bran 1 : 5.

The analysis of English produced meal shows 48.1 per cent protein digestibility and only 0·55 silica as ash.

PETAL AND FLORET MEAL

	Great Britain
Water	13·48
Crude Protein	10·50
Sol. Carbohydrates	35·30
Oil	6·41
Fibre	24·53
Ash	9·78

The above analysis is for the waste thrown off the second screen of the thresher and consists of petals, florets and small portions of leaf from an English crop, air dried. This should be compared with the sunflower head meal above. The higher protein and oil content, in spite of the increased fibre, seem to make this a valuable meal.

SILAGE

English figures (Jealott's Hill Research Station):

Water	81.7	Cut when seed in the milky stage.
Crude Protein	13.3	

ANALYSES

Canadian Department of Agriculture figures.

	A (cut when 10 per cent flowers in bloom)	*B (cut with seed fully formed)*	*Comparison with Maize Silage*
Water	75·67	52·31	75·47
Crude Protein	3·43	5·06	2·08
Crude fat	1·24	2·42	0·43
Carbohydrates	10·17	24·75	14·55
Fibre	6·22	10·16	1·95

SILAGE

Comparative figures of Sunflower and Maize for Digestible Nutrients —South Rhodesian Department of Agriculture.

	Water	*Prot.*	*Carboh.*	*Fat*	*Starch Equiv.*
A. Sunflower (outer flowers open, inner not)	75·00	2·3	10·5	0·9	12·2
B. Sunflower (top half, seeds formed)	75·0	2·4	10·2	1·0	12·3
C. Maize	75·0	1·0	13·6	0·6	13·3
D. Sunflower + Maize (Cobs: milky stage)	75·0	1·7	11·9	0·7	12·5

Note: The above sunflower silages were richer in protein and fat than maize silage, but starch value was lower. Although sunflower silage has a slightly lower feeding value than maize the higher digestible crude protein content of sunflower silage should give it an advantage over maize. It is important too to realize that sunflower can be grown successfully in seasons unsuitable to maize, especially through lack of rain.

COMPARATIVE ALBUMINOID (NUTRITIVE) RATIOS

Sunflower foliage	1 : 2·9
Sunflower Heads (deseeded)	1 : 6·0
Sunflower leaves	1 : 2·9
Lucerne	1 : 3·2
Sunflower head meal (5–10 per cent seed)	1 : 8·5
Wheat Bran	1 : 5·0
Groundnut Cake (decorticated)	1 : 0·9
Cottonseed Cake (decorticated)	1 : 1·2
Coconut Cake	1 : 3·9
Sunflower Cake	1 : 1·6

ANALYSES

Pea Meal	1 : 3·0
Soya Bean Meal	1 : 0·8
Sunflower seed	1 : 6·9
Linseed	1 : 5·8
Linseed Cake	1 : 2·1
Palm Kernel Cake	1 : 3·9

Note: Sunflower contains four to five times as much fat as cereals and more protein, the latter comparing closely with soya, peas, etc.

COMPARATIVE CAKE FEEDING VALUES

	Kling
Palm Nut	99
Coconut	104
Linseed	98
Sunflower	95
Cottonseed	54

It will be seen that feeding value of the first four is very little different; protein content, however, gives sunflower an advantage.

BUSHEL WEIGHT—SUNFLOWER

The weight of seed per bushel varies from 30 to 48 lb. The larger types of seed naturally yield lowest weight per bushel, e.g. small-seeded varieties, such as Sunrise and Jupiter 42–48 lb.; Pole Star, Mars and Southern Cross 39 lb.; large seeded black or striped Russian 35 lb.; giant white seeded, 30 lb. Much will, of course, depend on severity of winnowing for removal of blind seed.

CHAPTER XIII

SELECTION AND BREEDING

As has been pointed out none of the varieties at present grown in Britain, particularly Pole Star and Southern Cross, can be regarded as pure or fixed or likely to breed entirely true, though Mars and Jupiter seem fairly well fixed and Sunrise moderately so. On the other hand, undoubtedly, even better varieties can be arrived at by selection and breeding.

The main points to be aimed at are:

(*a*) Early ripening.
(*b*) Maximum seed yield.
(*c*) Maximum oil content.
(*d*) Highest kernel to husk ratio.
(*e*) Freedom from disease.
(*f*) Even ripening between plants.

Under (*a*) we have certain varieties that seem to meet our needs and give a fairly wide range suitable for different local climatic conditions. Unfortunately (*b*), (*c*) and (*d*) do not necessarily run together, so that selection and controlled cross breeding must be employed to improve existing varieties or produce new ones; (*f*) is a factor that needs attention, especially in Saturn, Pole Star and Southern Cross.

SELECTION

Multiheadedness is certainly undesirable as it reduces yield and renders harvesting and subsequent processes more difficult. Multiheadedness is inherent in some varieties, but to complicate matters, it can also occur, for non-genetical reasons, due to local conditions of weather or mechanical damage to the growing plant. Where it occurs as a result of a setback in growth, due to soil or weather conditions, it is impossible to distinguish from inherited multiheadedness. For this reason roguing must be severe in crops intended for reproduction, if this characteristic is to be bred-out.

Multiheadedness can usually be discovered at a very early stage, long before the central bud opens and therefore, if roguing takes place early, most of these plants can be removed and so have no chance either to

form their own seed or to cross-fertilize their neighbours. But roguing if done at all, is useless unless done drastically and meticulously. Every 'wrong-un' must be taken out. This means that roguing must be done several times and every plant in every row examined.

While plants that fail to bend their heads as the seed ripens are also undesirable, as they form bird-tables, usually the seed is taken from these by the finches before it matures. But it must be realized that even this condition may not be apparent until fertilization has taken place and pollen from these plants has cross-fertilized its neighbours. Likely bull-necked plants should be cut out as early as possible.

Naturally plants showing signs of disease, especially Botrytis, sclerotinia and the like will be uprooted and burnt immediately they are detected in any crop intended for seed for resowing.

The final roguing should take place after the seed has set and, though by that time it cannot be entirely effective, it will allow certain throwbacks, such as white seeded plants in a black seeded crop, to be removed.

Some variation in colour of seed is bound to occur in any of the varieties having grey or striped seed, since these varieties were originally crosses between black and white seeded varieties and, not being really fixed are, by Mendel's law, bound to throw back some white and some black seed. This actually has less importance as in most cases the next generation, after cross-fertilization, tends to strike the medium again.

Plants showing excess of height over the average of the crop should be discarded as, although this may be due to the soil in a particular patch, it is much more likely to show a tendency to 'giantness' which carries with it slower and later ripening and larger, more fleshy heads.

The cross fertilizing proclivities of sunflower make it entirely inadvisable to grow two crops of different varieties within a mile of one another.

When it is remembered that one acre of sunflower can well produce one ton of seed and that one ton of seed is sufficient to resow 220 acres it will be seen that large crops for reproduction purposes are not necessary. In any case roguing is far better done on small plots and, even if a large acreage is desirable of any one variety, it would be better to divide it into several well separated half-acre plots for ease of handling. Not only should attention be paid to exact row sowing, preferably sowing by hand on markers, but slightly wider inter-row spacing is advisable, to allow of those roguing passing easily between the rows. Also, with any variety, it would be preferable to sow at slight intervals in each succeeding plot, starting the first very early, so that all plots do not require roguing at the same time.

BREEDING

The breeding of sunflower is a much more difficult problem. As has been said, sunflower is practically self-sterile and fertilization is normally effected by insects. The use of muslin bags on the heads, to avoid cross fertilization by insects, is therefore essential and this means that artificial pollination—e.g. by cleansed hive bees—must be practised. This would be impossible on a large plot but small plots are very liable to severe bird damage (and birds may even peck through muslin) as well as being more susceptible to wind and, apart from the uprooting of plants, wind may cause setback, with consequent multiheadedness to those plants on the outside of a crop. It is therefore far better for the small breeding plot to be enclosed in the centre of a normal crop which will act as a shield.

We do not yet know what characters are dominants in sunflower: tall or dwarf habit (though probably the former); long narrow or short stumpy seed; compact or open heads; susceptibility to or immunity from certain fungoid diseases, etc. All these are matters awaiting investigation before we can make real headway in the breeding of truer and better stocks or new varieties.

Sunflower does present one advantage to the breeder, not usual in most farm crops. This is the fact that it belongs to the compositae and that a single seed will reproduce itself many hundred times in a single season and that on a single head which allows of easy control. When therefore one finds a sport showing probable or obviously advantageous characters, such as considerably earlier maturity than the rest of a crop, one can by artificial pollination of the florets on the single head, accompanied by adequate protection from cross-fertilization, obtain sufficient seed to sow at least an acre within two generations. In the same way a single head exhibiting seed showing certain advances in characteristics will produce many hundred seeds for the following year from which some further selection is possible, though there is always risk of some deterioration by possible cross-fertilization at an earlier stage if one depends on selecting from heads in which the seed is already set.

The most promising sports themselves will, of course, be the results of casual cross-fertilization.

CHAPTER XIV

VERNALIZATION

Practical vernalization of seed was the result of a method introduced by Lysenko in the U.S.S.R. in 1932.

The Russian term 'Jarovizacija', now latinized as 'Vernalization', is used in two distinct senses by Lysenko. Firstly it implies pre-sowing, which is now generally termed vernalization; and secondly, the first developmental stage, which winter cereals are incapable of completing naturally when sown in the spring, is also referred to as Jarovizacija or Vernalization stage. To avoid confusion, however, it has now been decided that 'vernalization' shall only be applied to the first developmental stage.

Briefly the object of Lysenko's method was to allow seed of plants, which was normally sown in winter, to be so treated that it would be artificially passed through the stages for which the winter months were normally used, before being actually sown. By this means winter grain could be sown in spring and reach the normal spring stage at the same period as if sown in winter. The main object, as far as Russia was concerned, was to enable winter varieties of wheat to be grown, from spring sowings, in climates that were far too cold for the normal method. Vernalization of wheat has, of course, more recently been carried out in this country.

Other crops besides wheat have been vernalized.

Under what circumstances might vernalization be profitably applied to sunflower?

Sunflower is universally looked upon as a crop that is sown in spring but in some climates, including our own, the period of summer is insufficiently long to allow the very tall varieties to be insured against harvest failure or bad weather in harvest, due to the fact that their long period of growth, seven months, under the most favourable conditions, makes it extremely risky to sow them in March or April.

Sunflower is known to be very frost hardy when in the ground as seed and also when in the cotyledon stage—a stage at which it will stand at least sixteen degrees of frost. But at a somewhat later stage, when in the fourth leaf onwards, it is far less hardy, probably because there is far less concentration of oil in any one part and far more water in the plant cells. It has been shown by Miller[1] and du Sablon that in the early

[1] *Ann. Bot.*, 1910, 24, 693; 1912, 26, 889.

stages of germination of seeds with high oil content there was little diminution though the amount of fat fell rapidly in the plant during the later stages of development. Miller used the sunflower for his experiments. With seed containing 56 per cent of oil at time of sowing the percentage was found to be reduced to 51·9 per cent when the cotyledons had emerged above ground. From then on the oil percentage fell rapidly having already fallen to 13·5 per cent when the cotyledons had fully expanded. There is a gradual increase in free fatty acids due to the hydrolitic activity of lipsase (du Sablon gives an interesting table showing this in connection with growing linseed). Miller found there was an increase in the acid value of the oil from sunflower during the time of germination.

So long as we are only concerned with growing the rapid-maturing semi-dwarf varieties we have no need to worry about the possibilities of vernalization. But it may well be found that the giant varieties—or some of them—are much heavier yielders and producers of a higher oil content than these semi-dwarfs. If this is so, unless we resort to some special technique, we must sow these giants much earlier, even possibly as a winter crop, in order not to run the risk of a failure at harvest time due to cold, wet weather and all its accompaniments—chiefly Botrytis.

But to sow earlier than March means running extreme risks of damage from frost in our uncertain climate. We cannot always anticipate mild winters or even mild early springs.

If it were possible, however, to vernalize sunflower so that, before the seed was actually sown in the ground, it would have passed through those stages which under natural conditions occupy some two to three weeks, by sowing in the first week in March we should stand a very good chance of harvesting a successful crop almost every year, especially as we now have a thresher which will take the heads as gathered from the standing plant and are advancing in the technique of artificial drying.

As Lysenko points out, the development of an annual seed plant and the growth of the plant are not identical phenomena, since by 'growth' he understands the increase in weight and volume of the plant at any particular stage. The complexes of external conditions necessary for the growth of the plant at any particular stage of development are not necessarily identical. In fact it is obvious that one can have rapid growth and slow development; slow growth and rapid development; or rapid growth and rapid development, according to conditions and factors involved.

Of the several stages of development which are passed through in regular serial order at least one stage—the thermo stage or stage of

vernalization—is passed through before the initials of the reproductive organs are laid down. The conditions required for this stage are low temperature combined with suitable conditions of moisture and adequate aeration. Lysenko states that the 'processes conditioning the sexual reproduction of cereals may occur not only in the growing plants, but also in a seed with an embryo which has just commenced development but not broken the seed coat'. It is this principle which forms the basis for the method of vernalization, in which the thermo stage is completed, not in growing plants, but in seeds just commencing their development. Experiments proved that in order to effect this the embryo must be awakened from the dormant stage and must be induced to start growth without breaking the seed coat, thus turning the seed itself into the equivalent of a growing plant. Though this theory was first developed for winter wheat it is now claimed that its application holds good for spring cereals and other types of plants.

The method aims at providing the plant with certain necessary conditions for the completion of a number of stages of growth before the sowing of the seed. The difficulty that arises is that the necessary conditions for the development of any particular kind of plant vary and therefore lengthy experiment is necessary before the correct technique to provide those conditions with any given species is found, by which the process of vernalization can be achieved. The first stage is the thermo stage and here the requisite temperature band must be found and similar temperature conditions applied. This temperature range will not only vary with different species but also with different varieties.

The second stage is the photo-stage where growth is affected or promoted by light and darkness. The seed is incapable of reproduction or growth until the thermo-stage is passed and the photo-stage cannot be effected until after the thermo-stage is complete. The photo-stage may, and usually does, also require a higher temperature range than the thermo-stage and may necessitate either long or short periods of daily illumination, according to the species or variety of plant.

Many experiments have been carried out in the vernalization of sunflower seed in Russia. Some of these have shown that the period of growth has been shortened between the time the seed was sown and the ripening of the harvest, while others have had no positive result. This seems quite reasonable to expect since different types of seed were used and these may, as has been shown, require different conditions and temperature ranges. Since, however, successful vernalization of certain varieties might enable better crops to be produced, where under normal practice such varieties could not be expected to grow successfully in

Britain, it seems worth while to carry out further experiments in this technique. It might even be that vernalization of the semi-dwarf varieties would be well worth while, if it enabled them to be grown in some of the more northerly parts of our islands, where shorter summers and wetter conditions prevail.

APPENDIX I

RESEARCH NOTES

The following Notes have been added as the result of work done since the main part of this book was written and, in order to bring the matter as far up to date as possible, (E. F. Hurt, Sept. 1946).

1. SPONTANEOUS HEATING OF SUNFLOWER SEED STORED UNDER ADIABATIC CONDITIONS

As a result of work done by H. R. Sallans, G. D. Sinclair and R. K. Lamour, published in the Canadian Journal of Research (1944, 22, F,181–90), it has been found that sunflower seed generates heat on storage if the water content exceeds 10.5 per cent. The heating effect is not caused by respiration of the embryo, but is due to growth of micro-organisms (micro-flora). This bears out what has been said in a previous chapter.

2. PROBLEMS OF MINERAL NUTRITION OF SUNFLOWER

Although observations made in Britain fail to show any increase in yield from the use of Potash, Phosphates or Nitrogen, considerable interest attaches to a report of work done on this subject in Russia, by T. T. Demidenko and N. M. Rukhlyadeva, in the Bulletin acad. sci. U.S.S.R., Ser. Biol., 1944, No. 1, 38–9, of which the English summary, given in *Chemical Abstracts* (Easton, Penn., U.S.A.), is as follows: 'It was shown that the critical period of P-utilization in sunflower is the period between sprouting and flowering, with an especially active state occurring up to the formation of the "basket". Critical N requirement occurs between basket formation and flowering termination. K is especially required between basket formation and the time of ripening. The sunflower is capable of storing nutrient elements in the early stage of growth, especially in the case of P and K, less in the case of N. Initially low concentrations of these elements with gradual increase with development show a positive effect on increase of the crop, as this procedure avoids the action of high concentrates on the young plants. Especially vigorous absorption occurs after the "starvation" period,

with maximum amounts of P going to plants deprived of N feeding; with K the picture is reversed. P feeding after the basket formation decreases the yield, perhaps because of antagonistic effect of PO_4 and NO_3 amions.' This should be taken in conjunction with the English conclusions, reached by the Agricultural Research Council, and not read to mean that the use of artificial fertilizers is beneficial except where there are proved deficiencies of the three elements in the soil.

3. SUNFLOWER AS A SOURCE OF ALPHA-CELLULOSE AND PLASTICS

The high content of cellulose in sunflower stalks is well appreciated though, except in Hungary, according to reports, no attempt has been made to utilize this commercially. On the other hand, apart from considerable work and commercial production of industrial products, notably alcohol, from the waste of various crops, there has more recently been serious investigation on the part of certain American research workers on the production of alpha cellulose, paper and plastics from the waste of oilseed crops. This work follows the lines utilized for the production of alcohols and hexose sugars from plant stalks, grain hulls, bran, etc., namely, the use of micro-biological agencies for the breakdown of the natural product. In this connection the report on the 'Twenty-five Years of Research on Fermentation Processes in Professor Coover's Department', drawn up by Leo M. Christensen and published in Vol. 19, No. 3, April 1945, pp. 249–54, of the *Iowa State College Journal of Science*, is well worth study.

4. SUNFLOWER SEED AS POULTRY FOOD

In view of what has been written earlier it is interesting to note that Dr. Halnan of the School of Agriculture, Cambridge, an expert on poultry nutrition, has published figures which show that sunflower seeds are not only excellent food for poultry but, on an energy basis and protein content, have a value approximately double that of wheat, oats or barley.

5. SUNFLOWER SEED MEAL FOR HUMAN FOOD

Apart from reports of the use of processed sunflower seed kernels as breakfast foods in America, the *Science News Letter*, Washington, D. C., U.S.A., quotes the following report in the American *Science* (April 27

1945) on the findings of Prof. and Mrs. Harry G. Day of Indiana University and Ezra Levin of Monticello, Ill. Sunflower seed was found to be an important source of B vitamins, superior to wheat-germ and corn-germ meals and far superior to defatted soya bean meal in this respect. Prof. H. H. Mitchell, of the University of Illinois, had already shown that where the oil was extracted from sunflower seed by a low temperature, solvent extraction process, the protein in the kernel residue was in the same class as that of oats, wheat and barley and this residue was nearly 50 per cent protein. Similar solvent extracted kernel residue was also experimented with for human food, and the Day-Levin report on the latter describes it as a 'palatable light grey powder', and shows that it could be satisfactorily blended with white flour, etc., to make very appetizing baked goods.

6. COMMERCIAL PROCESSING FOR PROTEIN VALUE OF FOOD PRODUCTS—SUNFLOWER

The *Journal of Nutrition*, U.S. (29, 13–25, 1945) points out that work done by H. H. Mitchell, T. S. Hamilton and J. R. Beadles (Univ. of Illinois) shows that the protein of sunflower meal, prepared from the residue of the kernels, after oil extraction, was found to be 94·3 per cent digestible with a biolvalue of 64·5. This was where, for the oil extraction, a heat solvent extraction process was used. It was shown that the value of the proteins was increased by heat processing and the explosion process, if not carried to extremes, increased the biological value. Frequently the commercial processing for oil extraction, due to drastic heat treatment, might be expected to exert a destructive action on protein, where the temperature exceeded 75 degrees. Owing to its initial high content of protein, 55·4 per cent dry basis, the protein net content of sunflower meal food, made in the above way, on low temperature extraction, was found to be higher than that of any other foods, such as soybean and coconut, tested, i.e. 33·7 per cent.

APPENDIX II

DRILL SETTINGS FOR SUNFLOWER

(*Report issued by G. E. Blackman, Imperial College, March 1945*)

Results of work done by the Agricultural Research Council in conjunction with the National Institute of Agricultural Engineering at Askham Bryan, Yorks, provide some useful figures in regard to seed quantities and drill settings for those who have to make do with the more common types of drills in use on farms, which are not suitable for drilling at as low a rate as certain selected implements. These are given below with approximate settings. (Where the rates per acre are also given for wheat, oats, barley, etc., the figures refer to those marked on the setting or given in the table inside the box lid.)

1. Massey-Harris 20A: 20 coulters at 7″; combined grain and fertilizer types. Also similar drills No. 20A, 11, 13, 15 coulter, combined grain and fertilizer type.

Setting:	Coarse side	Oats 5, Wheat 2 pecks/acre.
		Sunflower seed 19½ lb.
		Oats 6, wheat 2½ pecks/acre.
		Sunflower seed 26 lb.
	Fine side	Oats 16, wheat 7½ pecks/acre.
		Sunflower seed 16½ lb.
		Oats 17, wheat 8 pecks/acre.
		Sunflower seed 17½ lb.
	Cracking	More damage on fine side, but no practical significance on either.

2. Massey-Harris No. 5. Plain grain drill 11 and 13 coulters. Similar drills No. 4.

Setting:	Fine side	Peas	6	7
		Wheat	7	8
		Sunflower	16	20
	Coarse side	(Bean run)—Sunflower 30 lb. per acre, at lowest setting.		
	Cracking	None.		

3. Massey-Harris No. 30. 24 coulter plain grain drill. Similar drills No. 30, 16, 20 and 28 coulter plain grain drill.

Setting: Coarse side (Large side of feed wheel) 6-tooth driving sprocket on gear case.
(i) Gear case sett. 2 Barley 72, Oats 49 lb./acre.
Sunflower 17 lb./acre.
(ii) Gear case sett. 3 Barley 72, Oats 49 lb./acre.
Sunflower 20 lb./acre.
Cracking None.

4. I.H.C. COMB, GRAIN AND FERTILIZER DRILL. 19 coulters at 7". Similar drills, I.H.C., both plain and combined grain and fertilizer drills, 11, 13, 15 and 19 coulters.

Setting: Coarse side (Lowest setting) Wheat 41, Oats 75 lb./acre. Sunflower 23½ lb./acre.
Cracking Negligible.
Fine side Highest setting—Est. 15 lb. sunflower per acre, but not recommended because of large percentage of cracked seed.

5. M.M. 20 COULTERS at 6", Plain or Combine Drill.

Setting: 22—19—20 lb./acre.
Cracking Slight.

6. NO. 38 OLIVER SUPERIOR (1937) 16 coulters at 7". Similar drills, No. 38 Oliver Plain Grain Drills.

Setting: Coarse side 1—7 setting on gear case.
Oats 35 qts. Sunflower 15 lb.
1—8 setting on gear case.
Oats 46 qts. Sunflower 20 lb.
Cracking None.

7. SHEARER DRILL.

Setting: (i) Coarse side. Second gear; double cog 233 or A263, large side inwards. 14-tooth change sprocket.
Wheat, coarse side, 126 lb. Fine side, 49 lb.
Sunflower seed 22 lb.
(ii) Coarse side. First gear; double cog D263; 24 and 15, large side outwards. 20-tooth change sprocket.
Sunflower seed 17 lb./acre approx.

8. I.H.C. EXTERNAL FORCE FEED DRILL. 20 x 6 not combined. Similar drills: 12, 14 and 16 row 6" Plain—not combined grain and fertilizer drill.

Setting: 5 pecks (oat or barley scale) 13 lb. sunflower seed.
6 pecks (oat or barley scale) 18 lb. sunflower seed.
7 pecks (oat or barley scale) 22½ lb. sunflower seed.

Cracking No practical significance.

Spacing: Every third coulter sowing, giving row width of 18″. The last coulter on one side blanked off and the marker on the other side 12″ out from wheel.

9. McKay Sunshine Drill. Similar Drill, Suntyne.

Setting: Second gear with double cog D700.

Coarse side (i) Change cog, 14 teeth. Sunflower 15½ lb.
(ii) Change cog, 16 teeth. Sunflower 17½ lb.
(iii) Change cog, 18 teeth. Sunflower 20 lb.
(iv) Change cog, 20 teeth. Sunflower 21½ lb.

Spacing: Every third coulter sowing, giving row width 21″.

Note.—*Except in the case of Nos. 8 and 9 Drills above, where Spacing is given individually, it can be taken that every third coulter should be left open and the intervening coulters stopped up, if the coulter spacing is not adjustable. Setting is important as while most root drills of the cup type, universal drills and many corn drills can be adapted, improper spacing will result in cracking or crushing of the seed.*

APPENDIX III

'DO'S' AND 'DON'TS'

Do obtain seed of varieties found suitable for this country and the particular soil or district.
Do insist on a germination test and purity of strain.
Do select a site away from stackyards, built-up areas, tall hedges and overhead cables.
Do use land that will retain surface moisture at time of germination.
Do sow reasonably early.
Do consolidate the seed beds on light soils or sands.
Do follow the spacing instructions given.
Do ensure that a suitable dryer is near at hand.
Do allow your crop to get *fully* ripe.
Do clean your thresher immediately work ceases for the day.
Do seek expert advice when in doubt.

DON'T grow on land deficient in lime.
DON'T grow on hillsides and, if you must use sloping land, cultivate or plough across the slope.
DON'T grow on shallow soil, chalk beds or badly drained land.
DON'T plough semi-rotted dung in deep.
DON'T use artificials, unless there is a *very* marked deficiency of potash or phosphates, shown by laboratory test.
DON'T buy just 'any' seed.
DON'T imagine that sunflower responds to the same treatment as grain or root crops.
DON'T grow in less than one acre plots unless particular attention can be paid to the crop.
DON'T grow two varieties within a mile of each other, if seed is needed for reproduction.
DON'T sow on 'bouts' or ridges.
DON'T single with a hoe. Pull unwanted plants by hand, or cross block.
DON'T aim at large heads and excessive vegetation.
DON'T let weeds overtop young plants.
DON'T cut heads with more than three to four inches of stalk.
DON'T spoil your seed by using an unsuitable thresher.

DON'T dry at over 110° F. at any stage. It is best to start at a much lower temperature.

DON'T store seed in bags if over 12 per cent moisture.

DON'T grumble if birds take some of your seeds. Remember a robbed sunflower head is very noticeable but what sparrows take in a wheat crop is unseen.

DON'T blame the seed until you are sure the fault is not your own.

DON'T grow sunflower on the same plot in successive years.

DON'T re-sow your own seed unless carefully selected, and even then a fresh strain grown in another part of the country is, as with most crops, far preferable.

APPENDIX IV

NOTES ON CENTRALIZATION

Experience of the centralized area system of handling sunflower crops in 1944 shows that, while the existence of a central drying plant is not only essential but entirely satisfactory, it is not economical to try to thresh the crops in such a plant if the threshing machinery is a fixed part of the plant and intended to feed direct into the dryers.

In the latter case it is impossible to gauge the threshing intake necessary to deal with the inward flow of crops to the 'factory' and to maintain a steady feed to the dryers so as to allow of a continuous drying process. Either crops come in too fast for the threshing plant to deal with, especially in the case of jammed drums and screens, such as happen from time to time with very moist crops, or where excess of stalk is attached to the heads, in each case necessitating a stoppage and cleaning. Or, especially where acreage of crops is small and it is desired to keep the seed from each crop separate, part of the plant will be idle and, since the threshing apparatus is a fixture designed to feed direct into the dryer, it cannot be meanwhile used for other crops.

It therefore seems desirable that, in the first place, the number of shellers necessary to deal with the crops planned to be grown should be decided on, bearing in mind that the harvest season is a comparatively short one. In that case the machines can be allotted to work as desired and two or more separate crops threshed on the premises simultaneously, either for successive drying or for treatment by separate dryers. This method of planning also allows for threshers to be taken out to thresh crops on the field, sometimes a very desirable proceeding, especially where crops are suffering from bird damage or Botrytis and therefore need threshing without delay.

With proper organization of labour and pre-cutting of the heads, when hand labour is used for the latter purpose, it may be estimated that one thirty-inch sheller will deal with (*a*) one acre of well-dried heads in one and a half hours or (*b*) one acre of wet crop heads in two and a half hours, employing two men to feed and two to bag off and superintend drive and cleanliness of screens. These figures are based on the assumption that there are no waits due to insufficiently continuous supply of heads. On using these estimates time must, of course, be

allowed for cartage of sheller, if sent out to the farms, and at least one hour for cleaning each night.

Generally speaking, therefore, it would be better not only to thresh in a separate unit at the factory but to have surplus shellers in stock to send out to crops.

In such a case therefore it is necessary to have an open conveyor, fed at ground level, to take seed from bags or containers into the dryer. Grain hoppers are useless if accompanied by cup elevators, as the majority of seed from crops grown in this country will be too moist and sticky to flow. Such a conveyor, on the band system, is of course essential for the feeding of waste and shredded heads to the dryers and therefore, where the dryer is used for both purposes, is economical. Whether the material is taken up by bars on the band or by wide, shallow cups is a matter of choice, but the latter, similar to those used for feeding flax for threshing in many flax plants, seem the most suitable.

As regards the area to be covered by a central plant, a fifteen to twenty miles radius is ample.

Crops should be carefully arranged so as to provide as far as possible a succession of harvests to avoid a bottleneck. While it is helpful to have a succession of crops of the same variety so as to dispense with unnecessary cleaning of plant, if the seed is needed for resowing, considerable forethought will be needed to obtain the best results. Generally speaking it would be best to sow early ripening varieties first or these will catch up with the later ripening crops and so cause all harvests to come in at the same time. Early March sowings will ensure ripening in August and, barring bird attack—less likely at that time on account of their choice of other food, especially farm crops—such crops can be held over without fear of Botrytis, etc., such as may occur in September. But entire reliance must not be placed on the natural period of growth of different varieties as this period will be affected by soil and other local conditions and these must be carefully studied in advance if a proper succession is desired. Among other 'local' conditions are often those proclivities of certain growers to use artificials which, among other things, may considerably delay seed ripening.

Finally, though no detailed research has yet been done, moist seed must be dried within a few hours. Delay here means heating by enzymes or bacteria, which set up indestructible enzymes, which will cause considerable degradation of the seed as time goes on and no amount of artificial drying will counter this.

In other words this industry must be considered as dealing with a delicate mechanism in the agricultural economy and those responsible

for the organization of an area must realize that success can only be attained by complete pre-planning, long before the sowing season commences. This is just as complicated a matter as the running of a railway system, as it involves many factors, and no one man, unless he has a complete knowledge of all the issues and technique involved, including soils, fertilizers, mechanics and drying principles, as well as the background of chemistry, plant breeding, biology, bacteriology and so forth, can expect to cope successfully with a business which involves so many considerations. Where a central treating plant is contracting with growers it is unfair to the latter if their produce is spoilt or lost through failure in the drying technique or in planning of the harvests. Both such, as well as independent growers, with their own drying plants, or growers' associations will be well advised to seek the aid and advice of someone with experience on the technical side who, having not only experience, is also in a position to bring knowledge or advice to bear to prevent or cope with future unexpected events. After all, a doctor or a veterinary surgeon is called in in cases of accident, disease or expected disease and even pre-natal care has proved its value. Such supervision and advice can hardly be expected for nothing and it is a fact that 'free advice, like any other cheap article, seldom pays'.

In an industry such as this co-ordination is essential between finance, the planner, the grower, and all those who can play their parts in the technical questions involved, whether machinery designers or those trained in the sciences of biology, plant physiology, bacteriology, mycology, pestology, chemistry, and so on.

It would probably be advantageous if growing areas were adjacent to one another so that each can help the other out in case of breakdown of plant or other causes and it is certain that comparison of data, which should in any case be carefully tabulated each season, in regard to variety of soil and many other subjects, should be interchanged through some central body.

APPENDIX V

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APPENDIX VI

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